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Soil Survey of Iowa, Report No. 23—Winnebago County Soils

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SOIL SURVEY OF IOWA

WINNEBAGO COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils



Soil Survey Report No. 23
June, 1922
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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June, 1922

Soil Survey Report No. 23

SOIL SURVEY OF IOWA

Report No. 23—WINNEBAGO COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, W. G. Baker
and G. H. Artis



Farmstead on Clarion loam, Winnebago county.

IOWA AGRICULTURAL
EXPERIMENT STATION

C. F. Curtiss, Director
Ames, Iowa

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WINNEBAGO COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, W. G. Baker and G. H. Artis

Winnebago county is located in northern central Iowa, bordering on the state of Minnesota, and almost in the exact center of the northern boundary of the state. It lies entirely within the Wisconsin drift soil area. Hence the upland soils of the county are all of glacial origin and the terrace and bottomland types also are derived from the drift material.

The total area of the county is 399 square miles, or 255,360 acres. Of this area 249,854 acres or 97.8 percent is in farm land. The total number of farms is 1,627 and the average size is 154 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land of the county:

Acreage in general farm crops	193,418
Acreage in pasture	57,500
Acreage in farm buildings, feed lots, and public highways.....	14,892
Acreage in waste land	5,956
Acreage in crops not otherwise listed	898

The type of agriculture commonly practiced in Winnebago county at the present time is general farming and includes the raising and feeding of cattle and swine. Dairying is practiced to some extent, also. The livestock industry is increasing in importance, particularly the feeding of hogs. On practically all farms the sale of hogs provides the largest part of the income. The sale of corn out of the county is not large and most of this crop is fed on the farms. Oats are sold more extensively to outside markets and there is some outside sale of other crops. The income from dairying is considerable and this industry is gradually becoming of more importance.

There is a rather large area of waste land in the county, much of which may be reclaimed and made productive with proper methods of soil treatment. In most instances infertility may be traced to inadequate drainage; the installation of tile and drainage ditches may provide for the reclamation of considerable areas. There are other causes of unproductiveness, however, and in some instances special methods of soil treatment must be practiced in order to make the soils satisfactorily productive. In a later section of this report, special treatments which are particularly desirable for individual soil conditions will be suggested. In special cases, for more or less abnormal conditions, advice regarding treatment will be furnished upon request by the Soils Section of the Iowa Agricultural Experiment Station.

The general farm crops grown in Winnebago county in the order of their importance are corn, oats, hay, potatoes, wheat, barley, alfalfa and rye. The average yields and value of these crops grown in the county are given in table I.

Corn is the most important crop, both in acreage and value. Average yields of corn amount to 47 bushels per acre. Under favorable seasonal and soil conditions, very much larger yields of this crop are frequently secured. In 1920

*See Soil Survey of Winnebago county, Iowa, by W. E. Tharp, of the U. S. Department of Agriculture, and G. H. Artis, of the Iowa Agricultural Experiment Station.

TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN WINNEBAGO COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	73,200	29.3	47.0	3,440,000	\$0.47	\$1,616,800
Oats	57,500	23.0	47.0	2,702,500	0.36	972,900
Spring wheat	5,280	2.1	11.0	58,100	1.35	78,435
Barley	3,590	1.4	22.0	78,980	0.63	49,757
Rye	110	0.04	17.0	1,870	1.17	2,187
Hay (tame)	22,050	8.8	1.5	33,080	16.24	537,218
Hay (wild)	20,650	8.2	1.2	24,780	12.69	314,458
Alfalfa	70	0.02	4.0	280	19.23	5,384
Potatoes	968	0.39	149.0	144,232	1.22	175,963
Pasture	57,500	23.0	....	.....	....	.....

almost 30 percent of the farm land of the county was utilized for this crop. The larger portion of the corn produced is fed on the farms; much is sold in the local markets, and it is estimated that less than 10 percent is sold out of the county. There are more than 100 silos in the county and a good deal of the corn produced is used for silage.

Oats is the second crop in acreage and value, and is an important crop on practically every farm. Twenty-three percent of the total farm land of the county was in oats in 1920 and average yields of this crop amounted to 47 bushels per acre. A large part of the oats grown is sold and it is estimated that 40 to 50 percent of the production goes to outside markets. There seems to be a much larger sale of this crop from the rented than from the owned farms.

The production of hay in the county is large and the combined value of the tame hay and the wild hay almost equals the value of the oats crop. The wild hay consists of native grasses growing on poorly drained land which is unsuited for cultivated crops; 8.2 percent of the farm land of the county is in wild hay. The yield of tame hay in the county averages 1.5 tons per acre and the crop consists mainly of clover and timothy mixed. Some clover is grown alone, altho it is estimated that not more than 10 percent of the small grain acreage is sown to this crop. Practically all of the hay produced is utilized for feeding purposes.

Potatoes are grown on rather a considerable area with large average yields, making this a valuable crop. The production of potatoes, however, is sufficient only to supply the home demand.

Spring wheat is produced to some extent, with average yields of 11 bushels per acre, the varieties used being Marquis and Velvet Chaff. No winter wheat is grown. The growing of wheat is of very minor importance in the county.

Barley is produced on a small area, with good average yields, and there are also small areas of rye and alfalfa. The latter crop gives indications of becoming of value in the county and average yields of 4 tons per acre are reported. This crop should prove of particular value in connection with the dairy farming industry. Sweet corn is raised in the vicinity of Lake Mills and Forest City, and sold to the canning factories at those places. Average yields are estimated at from 4½ to 5 tons per acre.

*Iowa Yearbook of Agriculture 1920.

Small apple orchards are maintained on practically all farms for home supply. The Northwestern Greening, Wealthy, Duchess, Tetofsky and Yellow Transparent are the most successful varieties. There are several small orchards near Forest City, but the commercial production of apples is not practiced to any considerable extent. Cherries, plums, goose-berries, currants, red raspberries and strawberries are grown, but these small fruits are not produced as extensively as they might be. There is very little fruit production on rented farms and the fruit industry in general is developed to only a small extent on the owned farms.

Some sorghum is raised and utilized for syrup, and some flax seed is produced.

The livestock industries of the county consist mainly of the feeding of hogs and cattle, and dairying. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the extent of the livestock industries of the county:

Horses, all ages	9,276
Mules, all ages	216
Swine on farms July 1, 1920.....	52,682
Swine on farms Jan. 1, 1921.....	41,230
Cattle (cows and heifers kept for milk).....	12,327
Cattle (other cattle not kept for milk).....	19,666
Cattle, all ages	31,993
Sheep (all ages on farms Jan. 1, 1921).....	2,055
Sheep (shipped in for feeding, 1920)	1,248
Sheep (total pounds of wool clipped)	9,300
Poultry (total all varieties, Jan. 1, 1921).....	204,163
Poultry (number dozen eggs received, 1920).....	689,186

The feeding of swine is perhaps the most important livestock industry, the total number of hogs on the farms July 1, 1920, being 52,682. The sale of swine brings the largest income to most farms, and the greater portion of the corn crop is utilized as feed for the hogs. Cattle feeding is practiced to some extent, and a small number of sheep are shipped in for feeding.

The dairy industry is increasing in importance and on practically all the farms the sale of milk or cream provides considerable income. There are cooperative creameries in many of the towns; the total value of the dairy products sold out of the county amounts to many hundreds of thousands of dollars annually. In practically all cases the dairy industry is combined with general farming practice and the products of the farm are used very largely for feed and very little concentrates are purchased.

Poultry production is increasing in the county and the value of the egg production is considerable. Practically all of the eggs produced are sold in the local markets.

The value of land in Winnebago county is extremely variable, depending on the location with reference to towns and to railroad facilities, the improvements on the farms and natural soil conditions. The average price of the upland soils would range from \$150 to \$350 per acre. On the bottomland areas the price would, of course, be very much less, while a larger price is often secured for well improved farms.

The yields of general farm crops in Winnebago county have been fairly satisfactory, at least on the uplands, but in many cases more profitable yields might be secured by the adoption of better methods of handling the soils.

In many instances drainage conditions are not entirely satisfactory and when this is true, crop production will be low. It is necessary that many of the soils

of the county be tiled and in some instances ditching also is needed, if crops are to be protected from injury due to excessive moisture. No fertilizer treatment will prove of value on land which is too wet and even if the drainage of an area proves an expensive operation, the increased yields of crops secured will more than warrant the outlay.

Some of the soils of the county are acid and applications of lime are necessary. The amount of lime is not large in any of the surface soils of the uplands and even if the soil is not acid at present, acidity will develop and lime will be needed in the future. All the soils of the county should be tested at regular intervals for lime requirement and this material should be applied as needed, if the best growth of crops, particularly of legumes, is to be secured.

The upland types in the county, with one exception, are not rich in organic matter and applications of farm manure would be of value for increasing crop yields. In many instances the application of farm manure to the soils of the Clarion series has proved of great value from the crop standpoint. This is particularly true for the rolling phase of the Clarion loam. Even on those types where the organic matter supply is large, farm manure may be applied to advantage if used in small amounts, especially if applied immediately following the drainage of the soil. The bottomland types are not in need of manure, except in small amounts, as suggested, except in the case of the so-called alkali spots, which frequently occur in areas surrounding muck and peat deposits. On such areas the application of manure after the area has been drained is very important, if the excess of alkali salts is to be removed. It should be emphasized that for the maintenance of fertility in all the soils of this county and the keeping up of the organic matter content, farm manure should be utilized and all crop residues should be returned to the land. It may become necessary to use some leguminous crops, as green manures, also, if farm manure is not available, to keep up the nitrogen content of the soils, which must also be maintained if large crops are to be grown continuously.

The phosphorus content of Winnebago county soils is inadequate to supply any large number of crops, and additions of phosphorus fertilizers will become necessary in the future in all cases. There are many instances when phosphorus might be of value on these soils at the present time and farmers are urged to test the value of applications of rock phosphate or acid phosphate under their own soil conditions.

Erosion is active in some portions of the county, particularly in the rolling phase of the Clarion loam and in the steep phase of the same type. In many instances the washing away of the surface soil is being carried on by what is known as sheet erosion.

THE GEOLOGY OF WINNEBAGO COUNTY

The bed rock underlying the soils of Winnebago county has been buried so deeply under deposits of glacial drift that there is no effect of this rock material on the character of the soils. Hence it is unnecessary to consider the early geological history of the county prior to its invasion by the glaciers.

At least twice during the glacial age, great glaciers swept down from the north and, upon their retreat, left behind vast deposits of glacial drift or till. The

first of these drift deposits, known as the Kansan, consists mainly of what is now called blue clay and is extremely variable in depth. Apparently the original topographic features of the county were very largely obliterated when the Kansan till was deposited and the surface of the deposit was more or less level. This blue clay is very infrequently exposed and there is practically no effect from its occurrence upon the soil conditions in the county.

The later glacier, known as the Wisconsin, passed over the surface of the Kansan and the deposit of drift which it left behind upon its retreat covered deeply the earlier glacial material. It is from this Wisconsin drift that the soils of the county are derived and, even where erosion has been rather active for many years, there is only very infrequently any evidence in the surface soil of the earlier drift deposit. The Wisconsin drift is a pale yellow or light buff silt, clay and sand, containing some stones and boulders. In most instances 70 to 80 percent of the material is made up of silt and clay, the remainder being composed of medium and coarse sand. This buff-colored material is highly calcareous and in many places limestone fragments are numerous. Gravel and stony material of several kinds occur thruout the deposit, but in general the number of stones and boulders is small and they cause no difficulty in farming operations. On the morainic ridges, however,—those areas which mark the edge of the glacier,—there may be considerable deposits of stony material, with pockets of gravel. The surface material of this drift deposit has been very largely modified by weathering and the growth of vegetation and the color of the surface soil is generally dark brown to black. Much of the lime has been washed from the surface soil and, in the case of the Clarion soils, the most important types in the county, the surface soils are generally acid, while the subsoils may show a content of lime which in some cases is rather considerable.

The depth of this Wisconsin drift layer is extremely variable, ranging from 6 to 30 feet, on the average, for the entire county. There may be some instances where the blue clay of the Kansan is encountered at a depth of from 5 to 6 feet, but in general the Wisconsin material occurs in rather deep layers. Apparently the earlier topographic features of the Kansan deposit were not entirely obliterated by the Wisconsin glacier and occasionally on the knobs and mounds which occur in the county, there are remnants of the Kansan topography, with layers of Wisconsin drift extending over their surface. Gravel pockets, evidently of Wisconsin origin, frequently occur, sometimes on low knolls, and again at higher points. Occasionally these deposits may extend to a considerable depth. They are of no importance, however, from the soil standpoint, as their occurrence is entirely local and they are usually so far beneath the surface that they exert no effect on the soil conditions.

On the more level portions of the county the accumulation of organic matter in the soils has been greater and, as the drainage on these areas has been poor, lime has not been removed to such a large extent, and the Webster soils of the level uplands are consequently characterized by a black color and high lime content. On the more rolling uplands the accumulation of organic matter has been less and the color of the Clarion soils is usually a dark brown. These soils as a rule contain some lime in the lower layers and the subsoil is frequently a grayish-brown in color. In many cases, however, no lime is found to a depth of

3 feet, and thruout the areas of Clarion soils, there are areas which should really be mapped in the Carrington series. It is quite impossible to show these small areas of Carrington on the map, so they are included with the Clarion soils.

The terrace and bottomland types are derived from the drift soils of the uplands, and resemble them in appearance and general characteristics. The Waukesha loam on the second bottoms is very much like the Clarion loam, except that the subsoil is usually not calcareous, while the Fargo silt loam, representing an old lake terrace, resembles the same type of the Webster series. The area of bottomland in the county is small and besides the area of muck, peat and meadow, there is only one soil type mapped. This is a highly calcareous soil belonging in the Lamoure series and resembling the same type of the Webster series.

All the soils of the county, therefore, bear evidence of the more recent geological history, and this newer deposition of soil material, taken together with the more or less generally level topography and consequent accumulation of organic matter, indicates that the soils are comparatively fertile and that crop yields on them should be entirely satisfactory.

PHYSIOGRAPHY AND DRAINAGE

The topography of the western part of the county as a whole is almost level to gently rolling. The hills and ridges are low and rounded. The general slope of this upland plain is toward the southwest, and there is some drainage in that direction thru sluggish streams. In the eastern part of the county, the topography is strongly rolling to moderately hilly. This topographic condition is

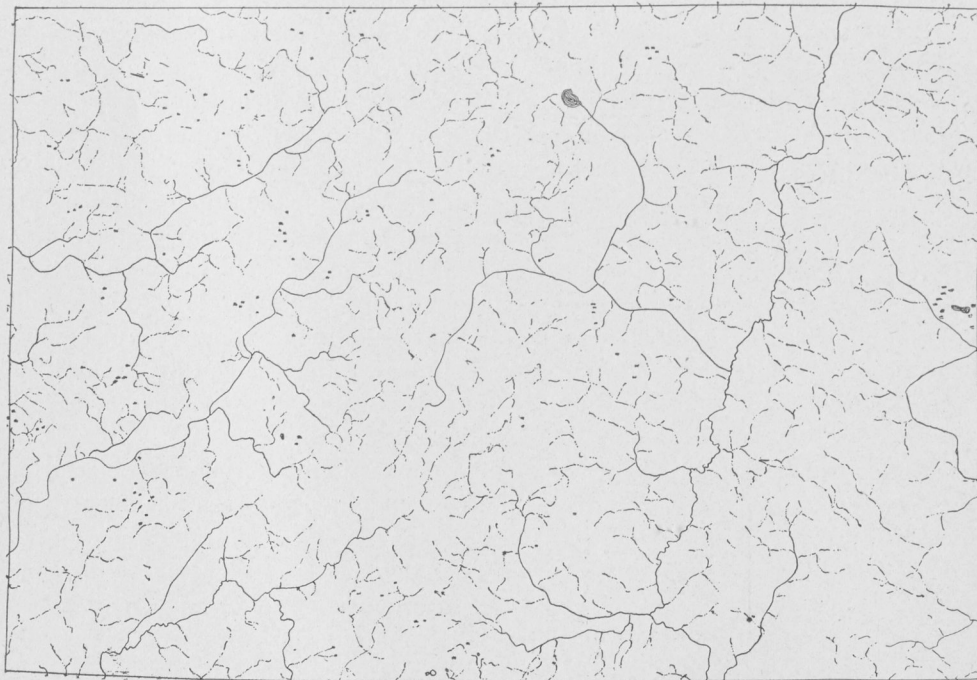


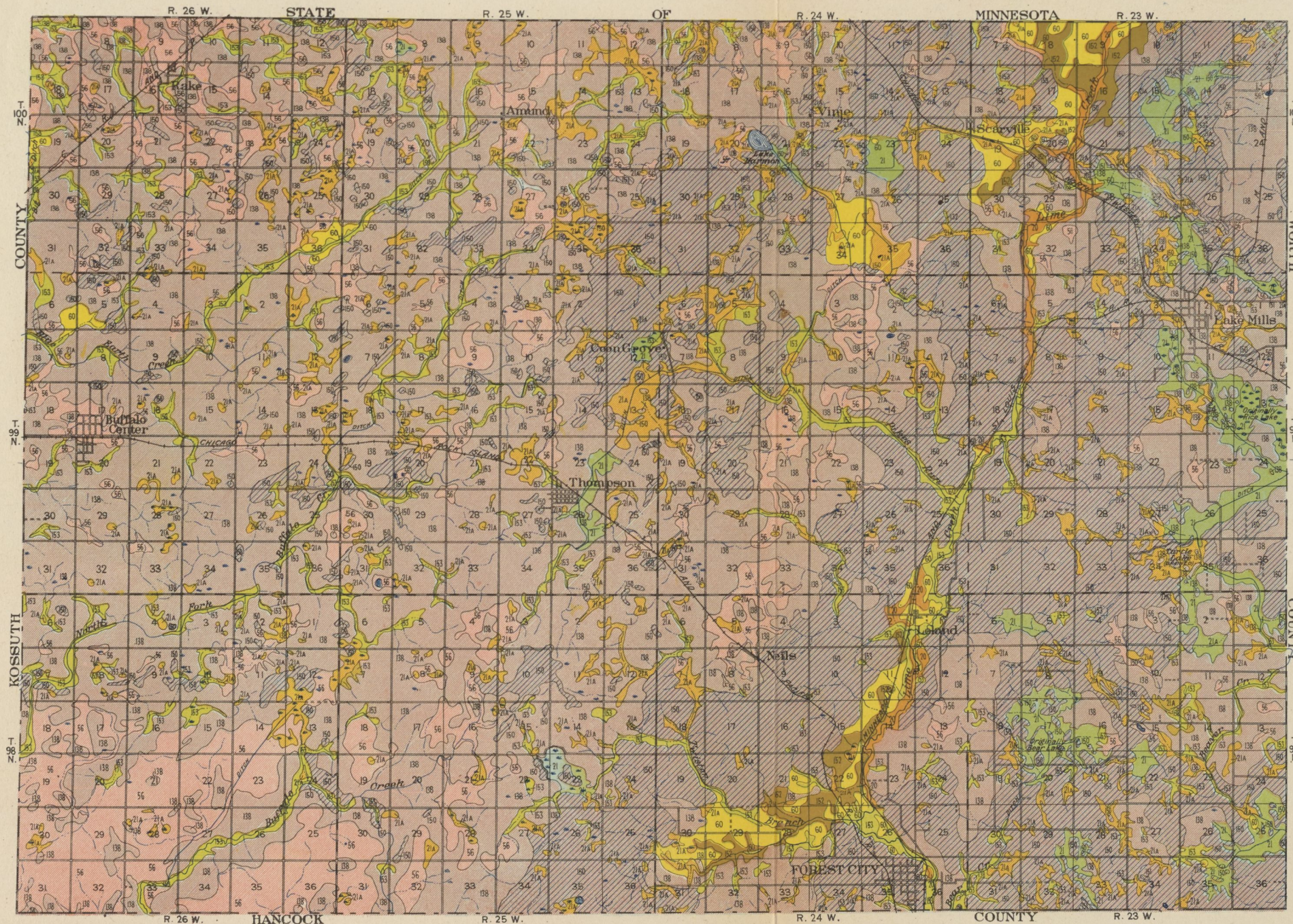
Fig. 1. Map showing natural drainage system of Winnebago county.

SOIL MAP OF WINNEBAGO COUNTY

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut, in charge Soil Survey

Thomas D. Rice, Inspector, Northern Division. Soils surveyed by W. E. Tharp, of the U. S. Department of Agriculture, in charge, and G. H. Artis of the Iowa Agricultural Experiment Station.

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C. F. Curtiss, Director. W. H. Stevenson, in charge of Soil Survey
P. E. Brown, Associate in charge

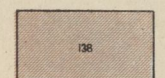


LEGEND

Drift Soils



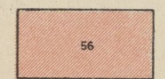
Clarion loam
(Rolling phase)



Clarion loam

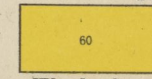


Clarion loam
(Steep phase)

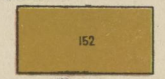


Webster
clay loam

Terrace Soils

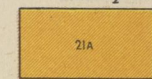


Waukesha
loam

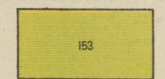


Fargo
silt loam

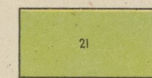
Swamp and Bottomland Soils



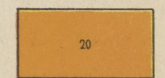
Muck



Lamoure
silt loam



Peat



Meadow

Scale: 1 Inch $2\frac{1}{2}$ Miles

MIDLAND MAP AND ENGINEERING CO.
DES MOINES, IOWA

known as the morainic topography and is characterized by knobby morainic hills and ridges, with more or less sharply defined outlines. These hills and ridges are irregular in distribution, occurring over rather large areas in the eastern part of the county and at scattered points in the western part. They are most pronounced in the vicinity of Forest City and north of Lake Mills. This rougher portion of the county is mapped as the rolling phase of the Clarion loam and is quite distinct topographically from the typical Clarion. The boundary lines between these types are generally very plain.

The drainage of the entire county is inadequate. The streams, flowing thru shallow channels, provide insufficient drainage even in their immediate locality. Blue Earth creek, North Fork Buffalo creek and Buffalo creek are the only natural drainage channels in the western part of the county and form only a very imperfect drainage system for that territory. Drainage conditions are little better in the rougher portions of the eastern part. Lime creek flows across the county from north to south, but it has few important tributaries and does not bring about adequate drainage, other than in a comparatively small area. Twister Branch, near Forest City, and Pike's Run, north of Leland, are the only important tributaries to this creek. In the southeastern portion of the county, Beaver creek drains a small area, likewise inadequately.

Ditches have been installed in many places in the county and provide artificial drainage for rather considerable areas. The accompanying map illustrates graphically the poor drainage conditions in the county, showing the very poorly developed system of streams and intermittent drainage ways, and the soil map likewise gives evidence of the poor drainage conditions. Muck occurs in all parts of the county in small, irregular-shaped areas, many of which are still under water, as indicated on the map by swamp symbols,—definite evidence of poor drainage. Then, too, there are considerable areas of peat, particularly in the old lake beds in the eastern part of the county, indicative of the swampy condition of the land in the past. In addition to these areas of muck and peat, there are numerous small areas and some larger areas of the Webster clay loam, a level, poorly-drained upland type. These areas of peat and muck and poorly-drained Webster clay loam are surrounded by the Clarion loam or the rolling phase of the same type, and from the close association of these types it is evident that the drainage of the Clarion soils may be inadequate in many cases. Tiling is necessary in many parts of the county and there is undoubtedly need for the installation of more ditches, as so many times tile cannot be utilized until a ditch has been provided to carry away the water draining from the tile. It is absolutely necessary that artificial drainage channels be provided to make up for the inadequate natural drainage system of the county.

THE SOILS OF WINNEBAGO COUNTY

The soils of Winnebago county are grouped into three classes, according to their origin and location. These are drift soils, terrace soils, and swamp and bottomland soils.

Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glaciers retreated. They are variable in

composition and may contain pebbles and boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them, or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly-drained areas, or along streams, and they are subject to more or less frequent overflow.

The extent and occurrence of these three groups of soils in Winnebago county are shown in table II.

By far the largest portion of the county is covered by the drift soils, 83.9 percent being in drift uplands. There is a very small acreage of terrace types, only 2.5 percent of the county being covered by these soils. The swamp and bottomland soils are more extensive, covering 13.6 percent of the total area and occurring in many small areas in all parts of the county.

There are five individual soil types in the county and these, together with the rolling phase of the Clarion loam, the steep phase of the same type, and the muck, peat and meadow, make a total of ten separate soil areas. There are four drift soils, including the phases mentioned, two terrace types and four swamp and bottomland soils. These various soil types are distinguished on the basis of certain characteristics, which are described in the appendix to this report, and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Clarion loam is the largest individual soil type, covering almost half of the total area. The rolling phase of the Clarion is the second largest soil in the county, covering more than one-fourth of the total area. The typical Clarion and the rolling and steep phases together cover almost three-fourths of the county, 73.2 percent of the total area. The Webster clay loam is the third largest soil type in the county, covering 10.7 percent of the total area. There is a rather considerable total area of muck, 5.2 percent of the county being occupied by this soil. Almost the same area is covered by the Lamoure silt loam, the only true soil type occurring in the bottoms. There are several areas of peat, together making a total of 2.7 percent of the total area.

The topography of the uplands of the county is very closely related to the soil type occurring on them. Where the Webster clay loam occurs, the topography is level to depressed; the typical Clarion loam shows a gently undulating topography, while the rolling phase, as the name indicates, has a much more pronounced rolling topography. The steep-phase Clarion represents the extreme topographic condition. The terraces and bottoms of the county are topographically level to depressed. In those portions of the county where the Clarion loam and Webster clay loam are the important types, the drainage conditions are unsatisfactory and tiling and ditching are generally necessary. Where the rolling

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN WINNEBAGO COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	214,208	83.9
Terrace soils	6,464	2.5
Swamp and bottomland soils	34,688	13.6
Total	255,360	....

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WINNEBAGO COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
DRIFT SOILS			
138	Clarion loam	117,504	73.2
150	Clarion loam (rolling phase).....	68,928	
151	Clarion loam (steep phase).....	576	
56	Webster clay loam	27,200	10.7
TERRACE SOILS			
60	Waukesha loam	4,416	1.7
152	Fargo silt loam	2,048	0.8
SWAMP AND BOTTOMLAND SOILS			
21a	Muck	13,312	5.2
153	Lamoure silt loam	13,248	5.2
21	Peat	6,912	2.7
20	Meadow	1,216	0.5
	Total	255,360	....

phase of the Clarion occurs, the drainage conditions are better, but even in such a topography, artificial drainage is sometimes needed. The terrace types and swamp and bottomland types are level in topography and generally in need of artificial drainage if they are to be made properly productive.

THE FERTILITY IN WINNEBAGO COUNTY SOILS

Samples were taken for analyses from each of the soil areas in Winnebago county except the steep-phase Clarion, the peat, the muck and the meadow. The more extensive soil types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samples were taken with the greatest care that they should represent the particular soil types and that variations due to local conditions and previous treatments should be eliminated. The samples were drawn at three depths, 0" to 6 2-3", 6 2-3" to 20", 20" to 40", representing the surface soil, the subsurface soil, and the subsoil, respectively.

Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods, and the Veitch method was followed for the limestone requirements. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type and represent, therefore, the averages of four to twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is somewhat variable, ranging from 1,577 pounds in the rolling phase Clarion loam, up to 3,414 pounds in the Fargo silt loam. There is no apparent relation between the phosphorus content of the soils and the various soil groups. The average of the terrace types and the swamp and bottomland soils is somewhat higher than that of the upland soils, but the differences are not great. The variations within the various groups are larger than the variation between groups. There does seem

TABLE IV. PLANT FOOD IN WINNEBAGO COUNTY, IOWA, SOILS

Pounds per acre of 2,000,000 pounds of surface soil (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
138	Clarion loam	1,910	4,591	54,822	Trace	1,932
150	Clarion loam (rolling ph.).....	1,577	3,951	49,466	0	2,705
36	Webster clay loam	3,331	8,444	104,909	2,025	Basic
TERRACE SOILS						
60	Waukesha loam	1,980	6,584	88,600	0	1,546
152	Fargo silt loam	3,414	11,936	242,618	21,582	Basic
SWAMP AND BOTTOMLAND SOILS						
153	Lamoure silt loam	2,505	10,592	126,119	14,581	Basic

to be some relation, however, between the individual soil types or between the soil series and texture. Thus, the Webster clay loam is much higher than the Clarion soils and the Fargo silt loam is higher than the Waukesha loam. There are not enough types of the same series in this county to permit of any extended comparisons from the texture standpoint and it merely should be noted that the rolling phase of the Clarion is lower than the typical Clarion. In general, it seems that variations in phosphorus supply in the various soils of this county may be related to the topographic condition, at least in part. But the soil texture undoubtedly affects the phosphorus content, also. Thus it might be expected that the Webster soils would be higher in phosphorus than the Clarion soils, owing to their more level topography and generally poorly-drained condition and also owing to the fact that crop production has been less on these types in the past because of their inadequate drainage. The texture of the soil, however, is important and a clay loam would naturally contain somewhat more phosphorus than a loam, especially when a comparison is made between these types in the Webster series and the Clarion series. Hence there are several reasons for the better supply of phosphorus in the Webster clay loam than in the Clarion soils. A similar comparison might be made between the Fargo and the Waukesha soils. The Fargo silt loam occurs in poorly-drained depressions. Crop production has been less, drainage has been poor and hence the phosphorus content is naturally higher than in the Waukesha loam. Furthermore, the silt loam might be expected to contain more phosphorus than the loam.

In general, there is no large supply of phosphorus in the soils of Winnebago county and phosphorus fertilizers will undoubtedly be needed in the near future if satisfactory crop yields are to be secured. Even if these materials are not of large value at the present time, phosphorus must be considered in planning systems of permanent fertility. The total supply of phosphorus in soils is not a definite measure of the phosphorus which is available for crop use, but merely serves as an indication of the amount which may be available for the use of future crops. It is generally assumed, however, that if the soil conditions are satisfactory and there is a reasonably large total supply of phosphorus, sufficient of the element will be changed to an available form to provide for crop growth. On the other hand, if the phosphorus supply is low in soils, the production of available phosphorus is almost certain to be insufficient. It is evident, there-

fore, that phosphorus fertilizers may prove of value on some of the soils of Winnebago county at the present time. Farmers are urged to test these materials on small areas on their own farms and thus determine for their particular conditions the need of phosphorus and which phosphorus fertilizer can be used most profitably.

The nitrogen content of the soils of the county is quite as variable as is the phosphorus supply, but the amounts of nitrogen are very much greater. There is no relation apparent between the nitrogen in the various types and the different soil groups which should be considered conclusive, owing to the fact that the number of soil types is small. The terrace soils and swamp and bottomland soils are higher in nitrogen than the upland types, which, of course, is due primarily to the fact that these soils have been cropped to a smaller extent and have lost less nitrogen by drainage. The differences in nitrogen content seem to bear more relation to the soil series or to the particular type. Thus the Webster clay loam is much better supplied than the Waukesha loam. This might be expected because of the characteristics which serve to distinguish the Webster and Fargo series from the Clarion and Waukesha soils. There is, however, an additional reason for the greater nitrogen content of the Webster and Fargo soils in this county, and this is that the types in these series are heavier-textured than the Clarion and Waukesha soils which are mapped in the county. In general, it might be expected that soils of a heavy texture and level to depressed topographic position, with consequent poor drainage, would contain more nitrogen, a condition which is found actually to exist in this county.

It is evident from these analyses that the soils of the county are in general fairly well supplied with nitrogen; in some cases there is a large amount present. This does not mean, however, that nitrogen may be disregarded in systems of permanent fertility. If the nitrogen content of the soils is to be kept up continuously, some nitrogenous fertilizing materials must be used at regular intervals. Farm manure returns to the soil quantities of nitrogen which are removed by the growing crops and is therefore an important nitrogenous fertilizer. On the rolling phase of the Clarion loam there is more need for this material than on the other types in the county. The typical Clarion loam and the Waukesha loam would also respond to farm manure and it is very necessary that the nitrogen content be maintained on these types. On the Webster, Fargo and Lamoure soils, manure should be used only in small amounts and never preceding a small grain crop, to avoid causing the grain to lodge. Small applications of manure, however, are frequently desirable on these types when they are thoroly drained and brought under intensive cultivation. The use of crop residues aids in keeping up the nitrogen content of the soil and these materials should never be wasted.

On the grain farm where manure is not available for use, and on the livestock farm where insufficient manure is produced for all the land, the nitrogen content of the soils may be kept up by turning under all or part of well-inoculated leguminous crops. Legumes, when well inoculated, derive a large part of their nitrogen from the air and when turned under in the soil, serve to increase its nitrogen content. Where the entire crop is removed, there would be no increase of nitrogen in the soil; neither would there be any reduction. Where the

seed only of the legume is removed, there may be considerable addition of nitrogen to the soil and if a portion of the crop is returned, the nitrogen in the soil may be increased in proportion to the amount of crop turned under, depending, of course, upon the thoroughness of inoculation.

There is a rather distinct relation between the nitrogen and organic carbon in most soils. The organic carbon is a measure of the organic matter in soils and the color of the soil indicates quite definitely the amount of organic matter and indirectly, therefore, the content of organic carbon and nitrogen. If the soil is black in color, the amount of organic carbon and nitrogen present is high. If the soil is light in color, the supply of these constituents may be low. The soils of Winnebago county are all dark in color, many of them black; hence, the supply of organic carbon in the various soils might be expected to be considerable. This is actually the case and the amount of organic carbon is found to range from 49,466 pounds to 242,618 pounds. Very much the same relations hold true for the organic carbon in the various soil types as in the case of nitrogen. The soils of the Webster, Fargo and Lamoure series are very much higher in organic carbon than the Clarion and Waukesha soils, just as they are higher in nitrogen. This is indicated by the darker color of these types and is undoubtedly due to the heavier texture and more level to depressed topographic condition.

The relation between the carbon and nitrogen in soils gives rather definite evidence of the rate at which plant food is being made available. In the soils of this county it seems that there should be a satisfactorily rapid production of available plant food, judging from the relation between the carbon and nitrogen. However, in all instances where drainage is poor, small applications of manure seem to be of particular value, probably because of the stimulation of available plant food production. Hence it would seem that in many of the soils somewhat abnormal conditions will prevent the best production of available plant food constituents, in spite of the fact that the relation between nitrogen and carbon seems to be satisfactory. The stimulation of bacterial action and greater production of available plant food may explain the beneficial effects noted from the use of manure on soils which are abundantly supplied with organic matter, black in color, and apparently not in need of its use. Many of the soils of this county will respond to additions of farm manure and this material should be used especially on the Clarion soils, and with more care on the dark colored types, if the organic matter content is to be kept up. Under adequate drainage conditions and intensive cropping, the loss of organic matter from soils may be very rapid, and farm manure is the cheapest and most natural method of making up this loss.

Crop residues should all be utilized as an additional means of keeping up the organic matter supply, and on the grain farm the proper handling of the legume crop of the rotation is necessary in order to supply organic matter to the soil. By the use of these materials in addition to farm manure, or as substitutes for that material, the organic matter content of the soils of the county may be kept up under any system of farming.

There is no large amount of inorganic carbon in the surface soil of any of the upland types in the county. The Fargo and Lamoure soils, however, show con-

siderable amounts of this constituent in the surface soils and the Webster clay loam shows a small content. The Clarion and Waukesha soils are acid in the surface soils, but not to any great extent. In fact, the lime requirement of these types averages only about one ton. Hence, while the soils of the Webster, Fargo and Lamoure series show no need of lime, the Clarion soils should be tested for acidity and lime applied as shown to be necessary. The same may be said of the Waukesha loam and there are probably cases, also, where the Webster clay loam is slightly acid and in need of lime. However, in general this latter soil type is basic in reaction and lime is not needed. The need of lime in Winnebago county may be considered to be confined to the Clarion and Waukesha series, and the amounts required to remedy the acid conditions are comparatively small. With better drainage conditions in the county, and greater crop production, lime will disappear from these soils more or less rapidly and the soils will become increasingly acid in reaction. It is very important, therefore, that these soils be tested at regular intervals and lime applied as shown to be necessary. Legumes will not make the most satisfactory growth in acid soils and even if the surface soil only is acid, it is important to apply lime in order that the crop may get a good start and grow well in its early stages. Later, the legume roots may penetrate to the lower soil layers where lime frequently occurs. Lime seldom moves upward in the soil and even if the lower layers are high in carbonates, the surface soil must be neutralized by the use of lime if legume growth is to be satisfactory. It is urged, therefore, that farmers in Winnebago county test their soils in the Clarion and Waukesha series at regular intervals and determine their lime requirement, making the necessary application preceding the legume of the rotation.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre. Unless there are very large amounts of plant food present in the lower soil layers, there is little effect upon the fertility of the soil. Hence the analyses of the surface soils generally indicate quite definitely the plant food supply of the soil and, indirectly, its crop-producing power. The lower soil layers in Winnebago county are not extremely high in any plant food constituents, in general not higher than the

TABLE V. PLANT FOOD IN WINNEBAGO COUNTY, IOWA, SOILS
Pounds per acre of 4,000,000 pounds of subsurface soil (6 2-3"—20")

Soil No.	Soil Type	Total phos-phorus	Total nitro-gen	Total organic carbon	Total inorganic carbon	Limestone requirem't
DRIFT SOILS						
138	Clarion loam	2,386	5,175	65,362	Trace	3,348
150	Clarion loam (rolling ph.).....	2,918	4,540	51,066	0	5,666
56	Webster clay loam	4,103	5,585	73,678	16,321	Basic
TERRACE SOILS						
60	Waukesha loam	3,892	5,772	71,600	0	1,546
152	Fargo silt loam	4,027	10,004	197,900	20,100	Basic
SWAMP AND BOTTOMLAND SOILS						
153	Lamoure silt loam	3,757	7,594	104,316	35,684	Basic

TABLE VI. PLANT FOOD IN WINNEBAGO COUNTY, IOWA, SOILS
Pounds per acre of 6,000,000 pounds of subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem't
DRIFT SOILS						
138	Clarion loam	3,306	3,838	46,418	36,982	Basic
150	Clarion loam (rolling ph.).....	3,057	3,362	39,000	0	5,828
56	Webster clay loam	4,330	3,026	40,482	80,118	Basic
TERRACE SOILS						
60	Waukesha loam	4,970	1,848	32,784	2,628	Basic
152	Fargo silt loam	6,081	11,346	176,772	107,616	Basic
SWAMP AND BOTTOMLAND SOILS						
153	Lamoure silt loam	5,374	5,298	77,286	42,714	Basic

surface soils, so the fertility of the soils is influenced very little by the different subsoil conditions. It is not necessary to consider these analyses in detail, but attention may be directed merely to the fact that the needs of the soils, as indicated by the analyses of the surface types, are very largely borne out by the results on these lower soil layers.

Phosphorus fertilizers will be needed in the future and might possibly be of value in some cases now. The supply of organic matter and nitrogen is considerable in most instances, but farm manure, crop residues and leguminous crops must be utilized if the supply of nitrogen and organic carbon is to be kept up in the various soils. The supply of these constituents is not so large that crop production will go on indefinitely without any return. In most cases the lower soil layers in the county are well supplied with lime and show a basic reaction. Only the rolling-phase Clarion does not show a large amount of lime according to these analyses, but in many instances lime does occur in the three-foot section in this type, as is evident from other analyses. The lime content in the subsoil of this type, however, is extremely variable in depth, occurring many times below the three-foot section. The particular samples of the type analyzed here do not show lime in the three-foot section, but probably the lime layer would have been encountered at a slightly greater depth. In several of the soils the supply of inorganic carbon in the subsoils is very large, but as has been noted, the inorganic carbon in the lower soil layers has little effect on the surface soils and if they are acid, lime should be applied as needed. When these soils have been drained for a longer period and lime has been washed out and removed by crops, there will be a greater need for the use of this material. For the present it can merely be suggested that the surface soils of the Clarion and Waukesha series should be tested at regular intervals and lime applied whenever necessary.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Winnebago county in the attempt to learn something of the fertilizer needs of the soils and to secure indications of the value of certain fertilizing materials. These experiments were carried out on the Clarion loam and the Webster clay loam, the two most important types in the county. The treatments used in the experiments included the application of manure, lime, rock phosphate, acid phosphate and a complete



Fig. 2. Greenhouse experiment, wheat and clover on Clarion loam.

commercial fertilizer. The amounts of these materials applied were the same as are used in the field tests and the results of these greenhouse experiments may be considered to indicate rather definitely the results which would be secured in the field. Manure was applied at the rate of 8 tons per acre; lime was added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the experiments, clover being seeded about one month after the wheat was up.

The results of the experiment on the Clarion loam are given in table VII, the figures being the averages on the yields on the duplicate pots. Manure brought about very distinct increases on the wheat grown on this soil and the clover crop was also increased materially. The increase, however, was much more pronounced with the wheat. The addition of lime along with manure had a slight effect on the wheat, but showed no influence on the clover. This is rather surprising, as ordinarily the beneficial effects of lime are shown on the legume crop

TABLE VII. GREENHOUSE EXPERIMENT, CLARION LOAM, WINNEBAGO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	11.75	52.16
2	Manure	17.25	58.96
3	Manure+Lime	20.00	58.96
4	Manure+Lime+Rock phosphate	20.00	68.04
5	Manure+Lime+Acid phosphate	20.00	58.96
6	Manure+Lime+Complete commercial fertilizer	23.25	68.04

and not on the grain crop. In general, farm experience shows the beneficial effect from the application of lime on clover and it is recommended that the need of this soil for lime be determined before clover is grown and that the proper application of lime be made as found necessary.

The application of rock phosphate and acid phosphate showed no effect on the wheat, but the rock phosphate brought about an increase on the clover. The complete commercial fertilizer increased both the wheat and the clover crop. It would seem from these results, therefore, that the Clarion loam will respond profitably to applications of farm manure. Lime should be used when the soil is acid in reaction and there are indications that phosphorus fertilizers may prove of value. The results obtained in this test are not sufficiently complete to permit the drawing of definite conclusions regarding the relative value of rock phosphate, acid phosphate and the complete commercial fertilizer. Further tests in the field are necessary before definite conclusions along this line may be drawn. As far as the complete commercial fertilizer is concerned, it may yield profitable returns in some instances, but it is not expected that a complete brand will prove as profitable as a phosphorus carrier, inasmuch as the expense involved is much larger and the soils are not as much in need of nitrogen and potassium as they are of phosphorus. It seems probable that phosphorus fertilizers will yield greater returns economically than the complete brands. Tests on the individual farm are urged to determine the relative value of rock phosphate and acid phosphate.

The second greenhouse experiment was on the Webster clay loam and the yields obtained are given in table VIII. Again the effect of manure is definitely



Fig. 3. Greenhouse experiment, wheat and clover on Webster clay loam.

TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER CLAY LOAM, WINNEBAGO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	18.00	70.25
2	Manure	22.00	74.84
3	Manure+Lime	22.75	74.84
4	Manure+Lime+Rock phosphate	26.00	77.11
5	Manure+Lime+Acid phosphate	23.00	....
6	Manure+Lime+Complete commercial fertilizer	25.00	79.38

shown, the yields of both the wheat and the clover being increased very definitely by the application. In spite of the fact that this soil is comparatively well supplied with organic matter, the addition of farm manure seems to prove of value, probably due, as has been suggested, to the stimulation of bacterial action and the greater production of available plant food. The particular sample of soil used in this experiment was slightly acid in reaction, hence lime was applied. The amount of acidity was so small, however, that crop yields were not influenced by the application of the lime. In general this soil is not in need of lime and this material would not need to be used. Wherever the type is acid, however, to a definite extent, an application of lime should be made. As the soil is brought under more intensive cultivation and is better drained, the loss of lime will increase and the need of testing the soil and making applications of lime will increase with each year it is under cultivation. The additions of rock phosphate, acid phosphate and complete commercial fertilizer gave increases in the yields of both the wheat and the clover. Unfortunately the clover crop in the acid phosphate pots was very evidently abnormal and the results are not included here. The rock showed up somewhat better than the acid on the wheat crop and the commercial fertilizer likewise gave a larger effect than the acid phosphate, but smaller than the rock. On the clover, the complete commercial fertilizer proved slightly more effective than the rock phosphate. In general, definite conclusions cannot be drawn from these experiments regarding the relative merits of the two phosphorus fertilizers and the results should not be interpreted to show definitely the value of the complete commercial fertilizer as against the phosphates. Field tests are needed to show accurately the need of phosphorus on this soil, and also to determine whether the rock or the acid should be employed. These results merely serve to indicate the possibility of value from the use of phosphorus fertilizers.

In general, it appears that applications of manure are very desirable on the Webster clay loam. When this soil becomes acid in reaction, lime should be employed and there are strong indications of value from the use of phosphorus carriers. It is doubtful whether complete commercial fertilizers will prove as profitable as the phosphorus materials. Farmers are urged to test the use of rock phosphate and acid phosphate on their own soils and thus determine for their particular conditions which material would prove the most profitable.

FIELD EXPERIMENTS

The field experiments which have been started in Winnebago county have not yet been under way for a long enough period to permit of the publication of the

results secured. Such experiments must be continued for several years before the results from them can be utilized for the drawing of conclusions. The data obtained from these experiments will be published later in a supplementary report.

There are some experiments under way, however, in adjacent counties, which have been running for several years and the results from some of these fields may be included here in order to give some idea of the character of the results which may be secured in this county later. The results of these experiments should not be interpreted too broadly, as they have not been carried on for any extended period of time, but they do serve to indicate the needs of the soils of this county and the value which may come from the application of certain fertilizing materials.

These field experiments are all planned with the idea of determining the relative value of various soil treatments and they are laid out on land which is entirely representative of the individual soil type. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops to be sure that accurate results are secured. These fields include tests under the livestock and grain systems of farming, manure being applied in the former and crop residues being utilized instead of manure in the latter. Only the plots in the livestock system are included in the results given here, as there has not been opportunity for the crop residue treatments to show up very definitely yet. Other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. Limestone is used in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in the rotation, acid phosphate at the rate of 200 pounds per acre annually, and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. The plots in these experiments are 156 feet, 6 inches, by 20 feet, or one-tenth of an acre in size.

THE TRUESDALE FIELD

The results on the Truesdale field, Series I, are given in table IX. This field is located in Buena Vista county on the Carrington loam, as mapped in that county, a type which is identical with the Clarion loam of Winnebago county as far as the surface soil is concerned. The only difference between the types is that the Clarion loam contains some lime in the subsoil and, as this condition has little or no effect on the crop yields, the results of these field tests on the

TABLE IX. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY
Truesdale Field—Series I

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover tons per acre 1921
1	Check	38.9	56.5	57.2	1.40
2	Manure	44.3	57.1	57.9	1.20
3	Manure+Lime	46.4	58.1	59.2	1.60
4	Manure+Lime+Rock phosphate	54.4	58.7	64.7	2.45
5	Manure+Lime+Acid phosphate	49.6	58.7	64.9	3.30
6	Manure+Lime+Complete commercial fertilizer	49.6	58.7	64.7	3.10
7	Check	38.4	58.1	56.4	2.20

Carrington loam may be considered to apply very closely to the Clarion loam in Winnebago county and the effects noted may be considered indicative of the needs of the Clarion loam in this county.

In this experiment a complete four-year rotation has been carried out and the effects of treatment on two corn crops, one oats crop and one clover crop are shown. Manure brought about a distinct effect on the corn in 1918 and a smaller influence on the same crop in 1919. Very little influence was noted on the oats in 1920 and none at all on the clover in 1921. The yield on the manure plot in 1921 was evidently somewhat abnormal, as a smaller yield was secured than on the check plot. The beneficial effect of lime in addition to manure is apparent on all the crops of the rotation, showing up not only on the clover but on the corn and oats also. It would seem that lime may exert a beneficial effect indirectly on the grain crops of the rotation and the value of applying lime to this soil should not be measured entirely by the effect on clover, altho the legume crop of the rotation would undoubtedly be influenced most.

Rock phosphate, acid phosphate and the complete commercial fertilizer all brought about definite increases in the crops of the rotation, except the corn crop of 1919, which was increased to only a slight extent. The clover was affected to a much larger degree than the other crops, and with this crop the acid phosphate proved superior to the rock phosphate, while the complete commercial fertilizer was somewhat less effective than the acid phosphate. On the oats and on the corn in 1920, the three materials exerted almost identical effects. On the corn in 1918, rock phosphate seemed to be somewhat superior to the other materials. Apparently phosphorus may be of value on this particular soil type and the application of phosphorus fertilizers may lead to distinct crop increases. Further experiments are necessary before definite comparisons can be made between the rock phosphate and acid phosphate, but these results seem to indicate superior value for acid phosphate on clover. The complete commercial fertilizer does not seem to have any larger influence than the phosphorus carriers and in some instances shows a smaller effect. It seems unlikely, therefore, that these materials would prove as profitable as the phosphorus fertilizers, inasmuch as they are more expensive.

The results on Series II from the Truesdale field are given in table X for the years 1920 and 1921. The yield of oats in 1920 was very irregular and the clover in 1919 winter-killed. The results obtained on the corn crops in 1920 and 1921 are given here, however, as they largely confirm the conclusions reached from the results of Series I. Again the beneficial effect of manure is evidenced, def-

TABLE X. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY
Truesdale Field—Series II

Plot No.	Treatment	Corn bu. per acre 1920	Corn bu. per acre 1921
1	Check	47.5	32.8
2	Manure	57.0	39.7
3	Manure+Lime	59.0	41.8
4	Manure+Lime+Rock phosphate	61.2	38.1
5	Manure+Lime+Acid phosphate	62.1	40.1
6	Manure+Lime+Complete commercial fertilizer.....	64.0	44.4
7	Check	57.1	36.2

inite increases in corn yields following the application of this material. Lime in addition to manure gave a further increase and the phosphorus carriers all showed effects except the rock phosphate in 1921, and the yield on that plot was evidently abnormal.

It seems apparent from these field experiments that manure is a particularly valuable fertilizing material for the Clarion loam and beneficial effects will be secured from its use on the various crops which may be grown. Lime should be used when the surface soil is acid and beneficial effects from this material will be noted, particularly on the clover crop of the rotation. Phosphorus fertilizers seem to be of value on this soil and tests of rock phosphate and acid phosphate on small areas are recommended. If rock phosphate or acid phosphate yields a profitable increase on a small area, then the farmer may be sure that the use of that material will prove profitable on a large area. Complete commercial fertilizers do not seem to be of any greater value than the phosphorus carriers and in some instances they have less effect on crop yields. They may be employed, however, provided comparative tests show them to be of superior value under particular conditions.

PEAT SOILS

Peat is partially rotted vegetable matter, which consists either of swamp grasses, sedges, rushes, and flags, or of sphagnum moss, the former variety being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas, where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits of only very incomplete decomposition. Deposits of peat thus formed increase from year to year and with the long continuance of swampy conditions may become of considerable depth. When the glacier which once covered north central Iowa retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area, especially near the edges, and in these places lakes, ponds and marshes were formed because of the heavy, impervious character of the subsoil, and the formation of peat followed. It is mainly in the Wisconsin drift soil area that peat occurs in Iowa.

Winnebago county is located in this soil area and has several areas of peat, together making a total of 6,912 acres, or 2.7 percent of the total area of the county. The peat areas occur mainly in the eastern part of the county, the largest occupying what was formerly Bear lake and Rice lake. There are also rather large acreages of peat north of Lake Mills, west of Scarville in the vicinity of Thompson, and both west and east of Forest City.

A complete discussion of peat soils in Iowa and a report of certain experiments which have been carried out to determine their needs have been given elsewhere* and no extended consideration of these soils need be entered upon here.

There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value pointed out. They are composed of fibrous, fairly dry vegetable matter, extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and

*Bulletin 157, Iowa Agricultural Experiment Station—Improving Iowa's Peat and Alkali Soils.

the reported experiments on peat soils have dealt only with shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report refer, therefore, only to the shallow peats and are not at all applicable to deep peats.

The peat in Winnebago county is generally less than three feet in thickness and only in a few localities does it extend to a depth of more than four feet. Practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

The analyses of numerous samples of peat soils reported in the bulletin referred to, showed that they contained not only an abundance of nitrogen and organic matter, but also considerable amounts of lime. Their phosphorus and potassium content was rather low, but these elements were abundant in the clay which forms the subsoils of practically all the shallow peats in Iowa. The character of the subsoil plays a very important part, as will be seen in the treatments which are advised for the reclamation of peat soils. On this account the heavy character of the subsoils underlying the peats in this county is emphasized.

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story counties, and these tests were considered at length in the bulletin mentioned. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination, in the amounts in which such materials are generally applied to soils. In no cases were there any profitable increases in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and the untreated soils were only such as might well occur between duplicate plots.

It is apparent from the data given in those field experiments that the shallow peats in Winnebago county do not need the addition of commercial fertilizing materials to make them productive. Altho they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be profitable. The crop seems to be able to secure a sufficient amount of these plant foods from the subsoil, which is well supplied with them. Furthermore, peat soils contain an abundance of nitrogen and organic matter and applications of manure are not advisable. Not only is it of no special value, but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria into the peat and increase the speed of decomposition. In general, manure should not be used on peat soils, but should be utilized on land in greater need of organic matter and nitrogen.

DRAINAGE AND CULTIVATION FOR PEAT SOILS

What the peats in Winnebago county need to make them productive is the physical improvement resulting from drainage, cultivation and the growing of the proper crops on them.

The drainage of peat soils is the most important step in their reclamation. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall, are essential.

The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself, as in the latter case the compacting of the peat would bring the tile too close to the surface and relaying would be necessary. The tile should not be laid too deeply in the subsoil, as the heavy clay is impervious to the passage of water. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will permit of the ready passage of water into the drains.

Fall plowing is desirable for peat soils in order to expose the soil to the action of the frost, rain and snow during the winter and hasten the decay of the peat. Fall-plowed peats may be worked earlier in the spring; hence the seed bed may be more thoroly prepared.

Deep plowing of peat soils is also of considerable value, especially when the peat is very shallow and some of the underlying heavy clay, rich in phosphorus and potassium, may be mixed with the peat. The physical and chemical conditions in the peat are both improved materially by such a mixing and crop production is increased. Even in the case of deeper peats, where the subsoil is not reached by the plow, it is of advantage to plow to a considerable depth in order to open up the peat to the action of air and thus hasten decomposition.

Iowa peat soils which are not over 16 inches in depth should not be rolled, as such an operation may compact them too much and retard the decomposition of the peat. Where the peat is deeper than this, careful rolling may be of value in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening the decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivating the peat, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be luxuriant and interfere seriously with the production of crops.

Corn and small grain crops as a rule do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore it is not advisable to seed these crops on peat soils until several years after their reclamation, when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat to an extent which aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes, and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit of the successful growth of corn and small grain crops. When properly reclaimed, peat soils may become extremely productive and it is certainly advisable to attempt the utilization of the peat areas in Winnebago county. With proper treatment and crop growth they can be reclaimed.

"ALKALI" SOILS

So-called "alkali" spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

There are several areas of "alkali" soils in Winnebago county and, while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots, while other crops are affected to a less extent.

The origin of these spots has been discussed in another publication. They occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough, but always in a belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in the bulletin mentioned, and more in detail in a later publication, and it is apparent from the studies which have been carried out that the salts which occur are variable. The chief constituent is calcium bicarbonate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. A variety of other salts is also common to the Iowa "alkali" soils, magnesium carbonate, nitrates, sulfates and the carbonate and bicarbonate of sodium being frequently found. The amounts of these latter salts which make up the "alkali" content of Winnebago county "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium carbonate which always occurs, may prove injurious.

The "alkali" problem in Winnebago county and in Iowa in general is therefore less serious than in the west, and reclamation is more readily accomplished.

TREATMENT FOR ALKALI SOILS

The first treatment necessary for the reclamation of "alkali" soils in Iowa is proper drainage. "Alkali" spots do not appear until after a soil is drained, but this does not mean that the drainage produces the "alkali" condition. A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thorough drainage is essential for the removal of "alkali" salts from the soil and in draining a slough or pond, lines of tile should be laid around the low area, as well as thru the center. These two lines will then run thru the area where the "alkali" is most likely to appear and the washing out of any excess of salts will be much more rapid. The lines of tile may be brought together again below the slough and, if the area is rather wide, a third line of tile thru the center of the slough may be advisable.

If tile is properly laid when a pond or slough is to be drained, the occurrence of "alkali" spots may frequently be prevented. When the "alkali" spot is fully developed, as is sometimes the case in Winnebago county, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable

matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on "alkali" spots and should be used wherever available in sufficient amounts. In other cases, green manures or straw may serve, but where such materials are used, a small application of manure should be made along with them in order to hasten the decomposition processes, which in turn hasten the removal of the excess of salts. No other fertilizing constituents are of value in reclaiming "alkali" soils, as far as is known. The thoro drainage of the areas and the introduction of an abundance of organic matter are the most effective methods which can be employed.

THE NEEDS OF WINNEBAGO COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

Field experiments have just been started on some of the main soil types in Winnebago county and there is no data available as yet showing the value of various fertilizer treatments. The field experiments from Buena Vista county which are included in this report are located on a type which is practically identical with the predominant soil in Winnebago county, and the results of those experiments may be considered to indicate quite definitely the results which may be secured in Winnebago county. When the experiments which are under way in this county have been carried on for a period of years, definite conclusions may be drawn regarding the most economic treatments for the various soil types. For the present the suggestions which are made regarding desirable treatments are based only on the results of the laboratory and greenhouse tests and on the field tests from Buena Vista county. No definite recommendations are made in this report which have not been tested to some extent by individual farmers and proved valuable by practical experience.

Individual farmers are urged to test the use of various fertilizing materials on their own soils and determine their value for the particular conditions. Information secured in this way may be of much practical value to the farmer and will also be of interest and value to many others, for the results will aid in the solution of the problem of fertilization of the same soil types elsewhere. Many farmers are now carrying on tests on a small scale and are finding that such tests may be very readily planned and easily carried out. The Soils Section of the Iowa Agricultural Experiment Station will aid and advise farmers who wish to conduct tests on their own farms. Until the field experiments now under way are more complete and the results conclusive, the best suggestion which can be made is that various phosphorus fertilizers be tested on small areas and in this way the farmer may determine whether or not the soil needs phosphorus and likewise determine which material is of most value. No recommendations given in this report are made except those which have been shown by practical experience to be of value and which may be put into operation under any farm conditions.

MANURING

The soils of Winnebago county are fairly well supplied with organic matter in all cases and in some instances there is a very large amount of this material present. This is evidenced by the typical black color of many of the soils. It would not be expected, therefore, that manure would prove of as much value on the soils of this county as in the case of lighter colored, light textured types such as occur in other counties. It is surprising, however, to note the beneficial influence of farm manure even on those soils which are very well supplied with organic matter. On the more rolling uplands in the county manuring proves of large value and, in fact, there is no other fertilizing material which exerts anything like as large effects on crop growth, but even on the black level uplands, manure increases crop yields and the increases are large enough to be profitable. It seems apparent, therefore, that farm manure is a most valuable fertilizing material for use in this county and farmers should see to it that the manure produced on their farms is carefully preserved and applied to the soil in order to secure the largest crop yields, as well as to keep the soils permanently productive.

Manure exerts beneficial effects on soils because of its influence on chemical, physical and bacteriological conditions. It contains some of the essential plant food constituents, hence improves the chemical condition of the soil, and it also contains organic matter which has an important effect on the chemical condition of the soil. Many of the plant food constituents taken from the soil by the crops grown are contained in the manure, and if the manure does not undergo losses of these valuable constituents, it may return to the soil a very large portion of the plant food removed. Thus it lengthens the life of the soil, or in other words, prolongs the time until any of the essential plant food constituents become deficient. Both light and heavy soils are improved physically by the application of manure, the former being made more retentive of moisture and less open and porous and less subject to losses by leaching. Heavy soils are opened up and made less impervious and better aerated, and excessive moisture is more readily removed. This physical improvement of soils is reflected in a larger production of available plant food and may lead to a better feeding of crops. The physical effects of manure are due to its organic matter content and are the results of the effect of organic matter on soil conditions.

Manure contains enormous numbers of bacteria which bring about the production of available plant food in soils; hence, the addition of manure to soils will lead to more available plant food for crops. Not only is there greater bacterial action from the organisms introduced, but those already present in the soil are stimulated to greater activity and more available plant food is the result. On many of the soils of Winnebago county the beneficial effects of manure are undoubtedly very largely due to the bacterial factor, or in other words to the stimulation of available plant food production. Where the soils are low, poorly drained and high in organic matter, conditions are not as desirable for bacterial action as they should be and available plant food production may be low. When such soils are drained, opened up and cultivated, the addition of a small amount of manure, by merely introducing bacteria, may lead to more satis-

factory crop growth. In general, however, the beneficial effects of manure are probably due to its chemical, physical and bacteriological effects, combined. From the standpoint of permanent fertility, it exerts probably its most important influence by keeping up the supply of the individual plant food constituents.

The value of manure as a fertilizer for general farm crops is so great that it is surprising that so little attention is paid to preserving this material and providing for its application to soils with as little loss of valuable matter as possible. If it is stored in loose piles exposed to the weather, 70 to 90 percent of its value may disappear. When this occurs, the manure will exert only a small part of the beneficial effect on crops which ordinarily would be secured. Certainly crop yields will be increased to a very much smaller extent, and the loss of the fertilizing properties of manure thru improper storage means actual money loss on the farm. The farmer who does not take care of the manure on his farm is wasting one of his most valuable assets and that waste is reducing his income from the farm. There are various ways in which manure may be stored in order to prevent losses before application, and no one method can be recommended for use under all conditions. It may be stored in a covered yard, or in a pit; it may be composted; it may merely be protected from the weather; but whatever method is employed, it is very important that the manure be kept moist and compact and prevented from losing the liquid portion thru the leaching action of rains. In some instances it may be possible to apply the manure to the soil as produced. In such cases there is no storage problem and the largest possible effects may be secured from the application of the material.

When manure is applied as produced, or is carefully stored, it is estimated that 75 to 80 percent of the plant food removed from the soil by the crop grown may be returned to the land. It is important therefore that the livestock farmer see to it that he does not waste this important fertilizer, but takes precautions that he secure full value from its use. On the average livestock farm the production of manure is insufficient to permit of any large application to all the soils of the farm. The usual application is 8 to 10 tons per acre once in a four-year rotation. Larger applications than this are sometimes made, but it is not desirable to apply more than 16 to 20 tons per acre under any conditions, for general farm crops. If large applications of manure are made to one field, the remainder of the farm may suffer. Hence it is well to arrange the applications of manure at regular intervals and in reasonable amounts, in order to keep all the soils of the farm supplied. Smaller applications than those suggested above may be made with good results on the dark-colored level upland types in this county, and on the black terrace and bottomland soils, when the latter are drained, and on such soils the larger applications are not recommended nor desirable. Especially where small grain crops are to be grown on the heavier dark-colored soils, manure should not be applied immediately preceding the small grain crop, owing to the danger of lodging. In such cases, the manure should be applied at some previous time in the rotation.

The beneficial effect of manure on all farm crops has been shown by many experiments and is evident from much practical farm experience. It is very important, therefore, that this material be utilized on the farms of Winnebago

county as far as it is available and, if other fertilizing materials are employed, they should be used in addition to manure if economic results are to be secured. No other fertilizing materials will prove of as large value if manure is not employed. These statements apply, of course, only to the livestock farm. If farm manure is not available, then other sources of organic material must be employed.

On the grain farm some material must be chosen for use in place of farm manure and on the average livestock farm there is not sufficient farm manure to keep up the supply of organic matter and nitrogen on all the soils of the farm. In both cases, therefore, some practice must be adopted to take the place of farm manure and the use of leguminous crops as green manures is the practice which is recommended and which proves most economically desirable. Leguminous crops are the most desirable for use as green manures because of the fact that when well inoculated they possess the ability to take up nitrogen from the atmosphere and fix it in the soil, where it is available for the use of subsequent crops. Such crops may act, therefore, really as nitrogenous fertilizers. They have large value because of the organic matter which they supply to soils and it is because of this addition of organic matter that green manuring is considered the most desirable substitute for farm manuring. Non-legumes may be utilized as green manures. They add organic matter to the soil, but they do not increase its nitrogen content. When the nitrogen supply in the soil is adequate and the addition of organic matter only is needed, non-legumes may be used very profitably. In general, however, leguminous crops are much more desirable and prove much more profitable. There are many legumes which are available for use as green manures under a wide variety of conditions, so that some one may be chosen which will fit in with almost any rotation. Under grain farming conditions and, in some instances, under livestock farming systems, green manuring may be practiced profitably. It is a practice, however, which should not be followed blindly nor carelessly, as undesirable effects may result if the green crop does not decompose rapidly enough in the soil. If the soils are not sufficiently moist, green manuring may prove undesirable, owing to detrimental effects on the moisture conditions in the soil. Advice regarding the practice of green manuring under special soil conditions will be given by the Soils Section upon request.

The utilization of all crop residues, such as straw and stover, is a very important practice for keeping up the organic matter content of soils. These materials are often burned or otherwise destroyed, thus wasting material which would be valuable in keeping up the organic matter in soils. On the livestock farm such materials may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil, or they may be stored under proper conditions and allowed to decompose partially before application. It is particularly important that these materials be applied to the soils on the grain farm where there is no addition of manure, but even on the livestock farm, crop residues should be utilized in order to supplement the applications of manure. They not only add organic matter but they add much plant food and so are of large value in the maintenance of permanent fertility. Thru the proper use of crop residues and green manures, the grain farmer may keep up the organic matter content of his soils even without

the use of farm manure and frequently the livestock farmer must depend upon these materials to supplement the farm manure which is available for distribution on his land.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of the soils of Winnebago county is not very high in any case, and in some of the types the supply is not sufficient for any large number of crops. Hence it is quite certain that phosphorus fertilizers will be needed on these soils in the near future if the most satisfactory crop yields are to be secured. There are undoubtedly conditions under which phosphorus fertilizers would prove of value in this county at the present time. Even where the total supply of phosphorus is large, applications of phosphorus fertilizers may prove profitable if they supply the element in an available form, as the production of available phosphorus is often too slow to supply the proper amount for the best crop yields. When the total amount of phosphorus in soils decreases, however, it is well known that the amount of the element in an available form decreases much more rapidly, and a low content of total phosphorus indicates definitely the need of phosphorus in an available form.

There are evidences from the greenhouse and field experiments in this county that phosphorus fertilizers may prove of value at the present time on some of the soils of the county and it may very safely be concluded that phosphorus fertilizers will be needed on all the soils of the county in the near future if their fertility is to be maintained permanently. Farmers are urged to test the need of phosphorus on their soils by the application of a phosphorus fertilizer to a small area, and if profitable crop increases are secured and it is evident that phosphorus will prove of value, then they may make applications to large areas.

There are two phosphorus fertilizers which may be employed, rock phosphate and acid phosphate. Acid phosphate is more expensive than the rock but it contains the phosphorus in an available form and the element is therefore utilizable immediately by plants. Rock phosphate on the other hand has a low rate of availability and must be applied to soils in much larger amounts. The choice between these two phosphates must be made on the basis of the relative cost of the actual application and the relative value of the crop yields secured. The field experiments now under way are testing these two materials and comparing them and eventually it is hoped that definite recommendations regarding the use of these fertilizers may be made. For the present the experimental results will not permit of a choice being made and farmers are urged to test the value of both the rock phosphate and the acid phosphate on their soils, thus ascertaining for their particular conditions which material will prove more economically desirable. It is comparatively a simple matter to test the use of phosphorus fertilizers on the farm and farmers may readily make such tests as are suggested. Directions for the carrying out of tests are given in Circular 51 of the Iowa Agricultural Experiment Station. If one of the fertilizers applied gives a profitable increase in crop yield on a small area, then that particular material may be applied to a large area with the assurance of profit. Tests of phosphorus fertilizers on Winnebago county soils are very desirable and it is hoped that many

farmers will carry out such tests as are suggested and solve the phosphorus problem for their own conditions and at the same time aid in the solution of the problem for the whole state.

Most of the soils in the county seem to be rather well supplied with nitrogen, but the amount present is not sufficient to warrant overlooking this element in planning systems of permanent fertility. Where large crop yields are secured and drainage conditions are entirely adequate, there is a constant removal of nitrogen by leaching and by assimilation by growing plants. Hence nitrogen is being removed from soils constantly and some means must be employed to keep up the supply. The proper care and use of farm manure will aid materially in keeping up the nitrogen in soils, but this material alone is not sufficient, even on the livestock farm, where it is available for use in considerable quantities. On the grain farm some nitrogenous fertilizer must be employed, and leguminous green manure crops are the cheapest and most effective nitrogenous fertilizers which can be used. Frequently they are also important fertilizers for use on the livestock farm to supplement the manure. Every rotation should contain a legume, and if this legume is inoculated and the crop turned under in the soil, at least in part, there may be a considerable addition of nitrogen to the soil. Of course, if the legume crop is removed from the soil, the nitrogen content will not be increased. If it is to serve as a nitrogenous fertilizer, a large part of the crop must be turned under as a green manure. If only the seed of the legume is removed and the remainder of the crop is used as a green manure, much nitrogen may be added to the soil. Legume crops may often be used as catch crops and serve in this way to increase and maintain the nitrogen in the soil, as well as to build up the organic-matter content. The proper utilization of crop residues is an important means of cutting down the loss of nitrogen from soils and such materials may be considered to a certain extent as nitrogenous fertilizers. Commercial nitrogenous fertilizers may be utilized in small amounts as top dressings, but their use for general farm crops on the soils of this county cannot be recommended at the present time. If they prove of value when tested on small areas, they may be utilized, but in general leguminous green manures seem to be much cheaper and quite as satisfactory for keeping up the nitrogen content.

Earlier tests of the soils of the state have shown a large content of potassium in practically all cases. It is unlikely, therefore, that potassium fertilizers would prove of value for general farm crops. Only in soils where the production of available potassium is very low, due to improper soil conditions, would there be any possible need for adding commercial potassium carriers. If the soil is kept in the best physical condition from the standpoint of organic-matter content, and the moisture content is adequate, there is every reason to believe that sufficient potassium would be produced in an available form to supply the needs of crops for almost an indefinite period. Hence, potassium fertilizers cannot be recommended for general use on the soils of Winnebago county, but it is urged that precautions be taken to insure proper physical conditions in the soil for an adequate production of available potassium. It may be that a small application of a potassium fertilizer would be of value as a top-dressing for stimulating the early growth of some particular crop and occasionally newly drained

land has been found to respond to the application of potassium, but in these cases it is evident that the beneficial effect is due to the fact that there is an inadequate production of available potassium.

Complete commercial fertilizers cannot be recommended at the present time for general use in this county and it is believed that phosphorus carriers will probably prove much more profitable. Nitrogen may be more cheaply supplied by the use of leguminous green manures, and potassium is rarely needed. The chief value of the complete materials is due to the phosphorus content, and as phosphorus carriers are less expensive than the complete brands, if they give as large crop increases, they are certainly more desirable. The field experiments now under way in the county include the use of complete brands along with the phosphorus carriers, and eventually it is hoped that definite comparative data regarding the relative value of these materials will be available. At the present time it can merely be suggested that farmers who are interested may test any complete brands on small areas on their own farms at the same time that they are testing phosphorus carriers and if profitable results are secured, then the complete materials may be employed on larger areas with assurance of profit and, particularly, with the assurance of greater profit than from the use of the phosphorus materials. There is no objection to the use of complete commercial fertilizers if they are profitable, but it is very important that they be compared with the phosphorus carriers in order that it may be definitely determined whether or not they should be used.

LIMING

Many of the soils of Winnebago county are well supplied with lime, so that additions of this material are not necessary at the present time and probably will not be necessary for many years. The Clarion loam, however, and the rolling phase of the same type,—the most extensive upland soils in the county,—are acid in reaction in the surface and subsurface layers and in need of lime, if the best crop growth is to be secured. The Waukesha loam, too,—a terrace type,—is acid, and applications of lime are needed on this soil for the best growth of legumes. Even tho the lower soil layers are high in lime, as is generally the case thruout the county, if the surface soil is acid, lime must be added or satisfactory crops will not be secured. Lime rarely moves upward in the soil, while, on the other hand, it is constantly being washed out of the soil in the drainage water, so that there is a continual reduction in the amount of lime present in the soil. There is some utilization by crops, also, and in some instances the removal of lime from soils in various ways may very quickly cause the soil to become acid in reaction. Thus, even tho some of the soils in the county are at present apparently well supplied with lime, they will eventually need applications of this material, particularly if they have not been adequately drained and later are brought under satisfactory drainage conditions.

It is apparent that much of the upland in the county must receive lime at the present time or in the very near future, if the best growth of crops, and particularly of legumes, is to be secured. These soils should be tested at regular intervals and lime applied as shown to be necessary. The figures given in the tables

earlier in this report are merely indicative of the needs of the individual soil types and should not be taken to show definitely how much lime should be applied to the particular soil. Soils vary widely in lime requirement and even the same soil type may show a variable acidity. Hence, before lime is added to any soil, that particular soil should be tested in order that the proper amount of lime may be applied. Farmers may test their own soils for acidity or they may send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they may be certain that they are making a proper application of lime and that they are putting the soil in the best condition for crop growth. Furthermore, it should not be considered sufficient to test soils once and apply lime at that time only. The gradual removal of lime from the soil which has been mentioned, makes it necessary that soils be tested at regular intervals to determine the need of supplying this material. It is generally believed that if the soil is tested once in a four-year rotation, lime may be applied in a sufficient amount to last during the four-year period. This test should be made and lime applied preceding the clover crop or other legume crop of the rotation. This is necessary, as clover and other legumes are most sensitive to a lack of lime and larger yields of these crops are always secured on limed soils. Other crops of the rotation may show some effect from the use of lime and occasionally corn or oats may be increased by the use of this material. In general, however, the value of lime is evidenced mainly on the legume crop of the rotation.

Many tests under farm conditions have shown the beneficial effects of liming and the experiments reported in the preceding pages emphasize the value of using lime on acid soils in this county. Even when the clover crop alone is considered, the use of lime is a most profitable practice. If the indirect effects on corn and small grains are taken into account, the profit from the use of lime will be much greater. The value of the increased crop yields secured much more than offsets the expense involved in the application. The farmers of Winnebago county should see to it that their upland soils are tested and lime is applied as needed if they expect to secure the most satisfactory yields of legumes. Furthermore they should test their soils at regular intervals to keep up the supply of lime if the soils are to be kept permanently fertile and crop yields are to continue satisfactory. Further information regarding the use of lime on soils, loss by leaching, and sources from which lime may be secured are given in Bulletin 151 and Circular 58, of the Iowa Agricultural Experiment Station.

DRAINAGE

Many of the soils of Winnebago county are inadequately drained, as has been noted earlier in this report. The drainage map of the county shows definitely that the natural drainage system of the county is not satisfactory and the installation of tile and drainage ditches is necessary if the soils of the county are to be made properly productive. The Webster clay loam of the upland, the Fargo silt loam of the second bottoms and all the bottomland types are in need of drainage, if they are to be made properly productive. They are naturally fertile soils, but under the poor drainage conditions which are characteristic of the

types, crop yields are low and the first treatment needed is the removal of the excess moisture. In some areas of the typical Clarion loam on the upland, too, the drainage is not entirely adequate, especially the areas adjacent to the Webster soils. Here, also, the installation of tile is necessary.

Drainage ditches have been established in the county and considerable tiling has been done, resulting in greatly increased crop yields. Even altho the expense of draining is considerable, it is well warranted by the results secured. There is no other treatment which can take the place of drainage, and no method of fertilization will prove profitable until drainage has been effected. In general, it may be said that wherever the soils of the county are low and poorly drained, the use of tile is a necessary operation, in fact, the first treatment needed to make the soils properly productive. There are still extensive areas in the county that may be made to produce large crops if they are tiled out and where there are no natural outlets for the tile, it may be necessary to install drainage ditches.

THE ROTATION OF CROPS

The continuous growing of any one crop rapidly reduces the fertility of soils and it is very important and even necessary that a rotation of crops be practiced on all soils, if they are to continue to be satisfactorily productive. Even if the particular crop which is grown is of considerable value, the income from the land over a period of years will be greater if a rotation is practiced. The gradually decreasing yields under continuous cropping reduces the income from land to such an extent that even less valuable crops in the rotation will be worth more than the money crop and if the money crop is rotated with other crops, the yields will not be reduced and consequently the total value of the crops of the rotation will be greater. There are many rotations which may be practiced, and no one rotation can be recommended for all conditions. No special studies of crop rotations have been made in Winnebago county, but there are a few rotations which have proved of general value thruout the state and these are suggested. Almost any modification of these rotations or, in fact, any rotation may be utilized, provided a legume is included. The following are important rotations in use in the state:

I. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.)

Second Year—Corn.

Third Year —Oats (with clover or with clover and timothy.)

Fourth Year—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.

Second Year—Oats.

Third Year —Clover.

Fourth Year—Wheat.

Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE-YEAR ROTATION

First Year —Corn.

Second Year—Oats or wheat (with clover seeded in the grain.)

Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur. Hence, it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will, of course, wash over it and much of the soil may be carried away in this manner, to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion, while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is generally the cause of erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues, if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil is exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but it is less harmful and is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is costly and inconvenient.

Erosion may occur to a considerable extent in Winnebago county in the rolling phase Clarion loam and also in the steep phase Clarion loam. Gullies are formed many times in the more strongly rolling areas of the former type, and there is much washing away of the surface soil over the entire type. It is very important that means be taken to protect this soil from serious injury thru erosion, and on the steep phase Clarion it will probably be most desirable to keep the type in permanent pasture where it is too steep to be satisfactorily farmed.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows," to small gullies, to large gullies, to bottoms, and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope, or even at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is usually customary to "plow in" the small gullies that result from these dead furrows and, in level areas where the soil is deep, this "plowing in" process may be effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside, at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES.

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the

gully. Brush is intertwined between the posts, straw is well tramped down behind them, and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch, but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is desirable before any success can be had in filling small or large gullies.

"Staking in." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of "dead furrow" gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case, consists in using the brush without stakes. The brush is cut so that a heavy branch, pointing downward, is left near the top. This branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems, and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed upstream instead of downstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brush piles may be installed up the course of the gully and, with the regular repair of washouts or undercuttings, may prove very effective.

A modification of this system of "staking in" which is being used with success in some sections consists in covering the bottom and sides of the ditch with straw for a distance of from four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend, of course, upon the size of the gully. These posts should be set into the ground and spaced about four feet apart, being arranged in a V-shape, with the point down stream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise, too large amounts of water may

accumulate above the dam and wash it out. In general, it may be said that when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided, the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or run-off to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides, to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later to seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey Dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" has been applied, hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made, of sewer tile with tightly cemented joints, and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory methods of filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams, the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory, and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish, even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven-wire, especially in connection with brush or rubbish, has sometimes proved satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" sys-

tem. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and, for quick results, sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water-absorbing power of the soil, decreasing the tendency toward erosion. Catch wells properly located over the surface, consisting of depressions or holes filled with coarse gravel and connected with the tile, help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES.

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS.

Erosion frequently occurs in bottomlands, and where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in any community and, while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows, which extend up the drainage channels. While the method has some good features,

it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general, it may be said that in pastures, bottomlands and gulches the presence of trees may be effective in controlling erosion, but a row of trees across cultivated land, or even extending out into it, cannot be recommended.

HILLSIDE EROSION.

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed, if farm manure is not available in sufficient amounts. Crop residues, such as straw and corn stalks, may also be turned under in soils to increase their organic-matter content. In general, it may be said that all means which may be employed to increase the organic-matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years, is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable for use in such locations. The root system of these crops holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and has proved very satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall-plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion, as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil will be reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

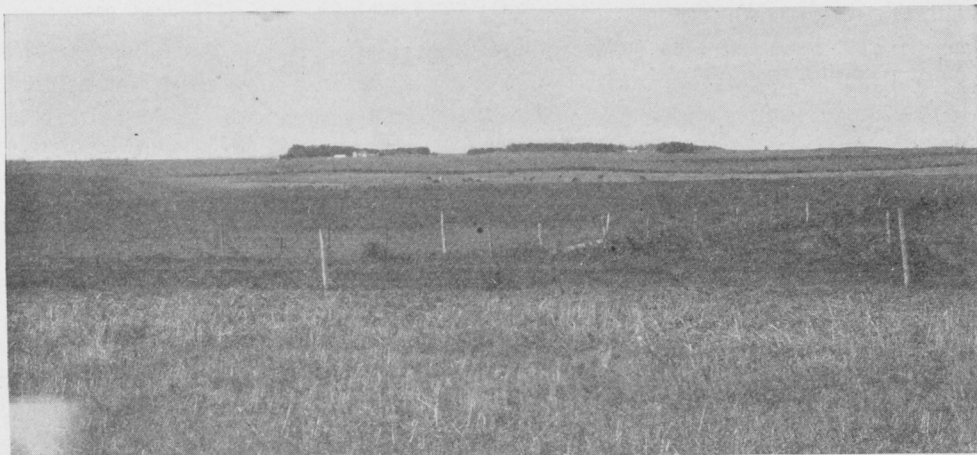


Fig. 4. Typical topography of Clarion loam in Winnebago county.

INDIVIDUAL SOIL TYPES IN WINNEBAGO COUNTY*

There are five soil types in Winnebago county and these, together with two phases of the Clarion loam and areas of muck, peat and meadow, make a total of ten separate soil areas. These are divided into three large groups, according to their origin and location, known as drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are two drift soils in the county, classified in the Clarion and Webster series. There are also two phases of the Clarion loam, making four drift soil areas. The total area covered by these drift soils amounts to 83.9 percent of the total area of the county.

CLARION LOAM (138)

The Clarion loam is the most extensive soil type in the county, as well as the largest drift soil, covering in its typical development 46.0 percent of the total area. It occurs on the uplands in all parts of the county, being developed to the largest extent in the western townships. Large areas of the type are found, however, thruout the eastern and central portions of the county, associated with the rolling phase Clarion loam on the uplands.

The surface soil of the Clarion loam is a black friable fine textured loam or silt loam, extending to an average depth of about six inches. From this point to a depth of about 20 inches there is a black or very dark brownish-black clay loam which gradually changes to a brown or yellowish-brown clay loam in the lower subsoil. The typical buff colored or gray calcareous material of the Clarion series frequently occurs within the three-foot section, but there are many instances where it appears only at greater depths. In fact, the depth to which this calcareous layer occurs is extremely variable and even within

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

comparatively small areas the calcareous material may appear in the three-foot section only in spots. The surface soil and subsurface soil of the type are quite generally acid in reaction and in some cases the subsoil may also show acidity, depending, of course, upon the occurrence or non-occurrence of the calcareous layer in the three-foot depth.

There is a variation of the typical Clarion where forest growth has affected the soil condition to some extent. In many instances this forest growth did not occupy the soil long enough to modify to any large extent the organic conditions and the surface soil is very similar to that of the typical prairie upland of the Clarion loam. In some areas, however, the effect of forest growth has changed somewhat the soil conditions and the amount of organic matter is decreased. Just below the surface soil a dull gray friable soil with thin streaks and specks of light gray has developed. The material often has an ashy feel and is very friable. This layer usually occurs between the depths of 10 and 20 inches and below it the characteristic brown clay loam of the subsoil occurs. These areas of forested soil are too small to be separated from the typical Clarion and are not shown on the map.

In topography the Clarion loam is undulating to gently rolling. The surface drainage in general is good, but there are some local depressions and sloughs included in the type, where drainage is poor. In the areas adjacent to the Webster clay loam, drainage is generally inadequate and tiling is needed. There are areas showing slight elevations, low mounds and ridges, and here the type approaches the rolling phase. In these areas there may be some gravel, sand or stones, but the subsoil is generally a loam and rarely a sandy or gravelly loam. Boulders occur thruout the soil, but not to any large extent.

Most of the Clarion loam is in cultivation and general farm crops are grown. Corn yields 40 to 50 bushels per acre on the average and, under favorable conditions, 60 to 70 bushels per acre may be secured. Yields of oats range from 40 to 80 bushels per acre, with an average of about 60 bushels on well-managed land. Barley is grown to some extent on this soil, which is also adapted to the growing of wheat. Clover is grown only to a small extent, altho it is



Fig. 5. Stock raising is practiced to some extent on the Clarion loam.

becoming more common to include this crop in the rotation. Small acreages near Forest City are utilized for fruit growing, and potatoes and garden vegetables grow well.

The Clarion loam is naturally a productive soil and crop yields may be satisfactory under favorable seasonal conditions. In many instances the type is in need of artificial drainage and tiling would prove of value. Applications of farm manure always prove beneficial, bringing about larger increases in yields of general farm crops. The surface soil of the type is acid and in need of lime, if the best growth of legumes is to be secured. Phosphorus fertilizers will be needed in the future and may prove of value in some cases at the present time. Experiments referred to earlier in this report show a large value from the use of manure on this soil and indicate the value from liming and the application of phosphorus. Much farm experience confirms the conclusions reached in regard to applications of farm manure. If this material is not available for use on the soil, it may be very desirable to employ a leguminous crop as a green manure. Farmers are urged to test the need of phosphorus on their soil and also the relative value of rock phosphate and acid phosphate. If these materials give profitable crop increases on small areas, they may be used profitably on larger areas.

CLARION LOAM (ROLLING PHASE) (150)

The rolling phase of the Clarion loam is the second largest soil in the county, as well as the second largest drift soil, covering 26.9 percent of the total area. It occurs most extensively in the eastern part of the county, covering large portions of the upland in the eastern half. It is associated mainly with the typical Clarion, but is spotted with areas of muck, peat, and Webster clay loam. A few small areas of the type are found in the western townships, but in this part of the county the type is very minor.

The surface soil is a very dark brown to black loam, containing some sand and a little gravel, and varying in depth from 5 to 6 inches on slopes, to 12 to 15 inches on the more nearly level areas. The subsoil is a dark brown crumbly loam or clay loam, becoming somewhat lighter in color at the lower depths. Below 20 to 24 inches it is usually a yellowish-brown clay loam, changing to a buff colored calcareous drift material just below the three-foot section. There are some local areas where the calcareous material occurs in the three-foot section. On the steeper areas and on the tops of mound-like areas, there is usually much stony material, consisting of gravel and small boulders, and the soil may be gravelly or a coarse sandy loam.

Near Lake Mills the phase varies somewhat from the typical description. In this locality it is a dark brown coarse-textured loam or sandy loam to a depth of 6 inches. From this point to 18 or 19 inches, the material is a yellowish-brown coarse-textured loam or clay loam. The lower subsoil is usually a sandy loam, changing with increasing depth to loose sand or gravel. The lighter-textured areas occur on the local elevations, while the heavier soil is found in the depressions and the gravelly layer may be below the three-foot section. On the higher points the drainage may be excessive, owing to the loose sand or gravel in the subsoil, but in the depressions the drainage may not be

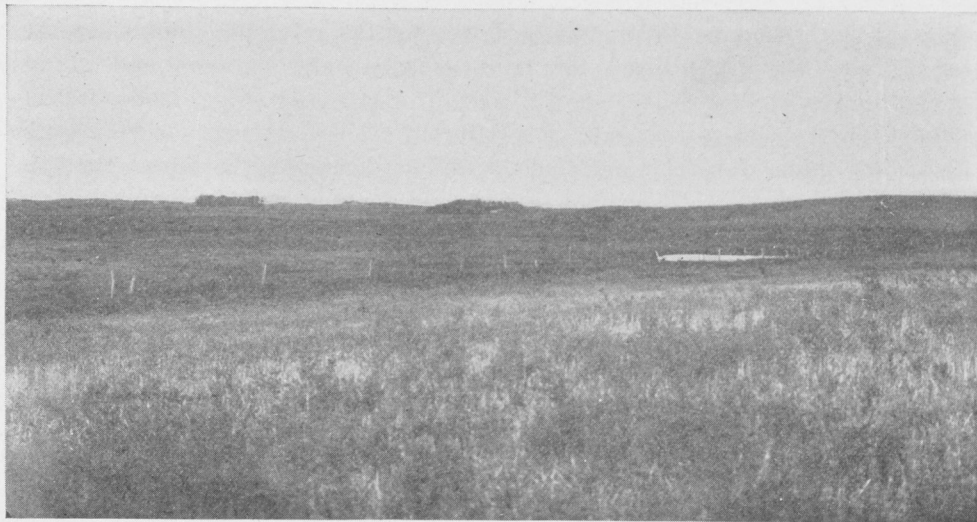


Fig. 6. Clarion loam, merging into the rolling phase in the background.

entirely adequate. This variation from the typical phase is found in some areas near Turtle Lake, five miles south of Lake Mills, but these areas are small.

In the areas east of Forest City the soil is somewhat stony and ranges in texture from a sandy loam to loam. As a rule the subsoil is a yellowish-brown clay loam, with the gravel occurring in pockets or spots. Some of the small, narrow areas near muck beds are low ridges of sandy, gravelly drift material, with varying surface conditions. The rougher areas have a scattering growth of bur oak and are in pasture, but nearly all of the areas are tillable.

The topography of the rolling phase of the Clarion loam varies from strongly rolling to hilly. In the central and western part of the county, the areas of this phase are ridges, which rise above the general level of the surrounding country. The areas near Coon Grove and to the north are quite hilly. The small areas on the borders of the muck are sandy, stony ridges. The areas between Scarville and Leland are generally high rolling ridges, the topography becoming more strongly rolling as the southern county boundary is approached. East of Lime creek the phase is less strongly rolling, but in small areas north-east of Lake Mills and near the old lake beds further south, there are sharp slopes, narrow ridges and many mound-like elevations. The roughest areas occur a few miles east of Forest City, forming the northern slopes of Pilot Knob.

The rougher areas of the phase are partly covered with brush and small timber and are generally used for pasture. Probably around 90 percent of the type is in cultivation and general farm crops are grown. The yields of corn, oats and other general farm crops are very much the same as on the typical Clarion loam. The yields of corn on the rolling phase are somewhat higher in seasons of heavy rainfall, but in normal seasons the yields are better on the typical Clarion. The large, later-maturing oats prove more satisfactory on this phase than on the typical loam. Variations in case of other grain crops are of little significance. Timothy and clover do well and bluegrass makes a very satisfactory growth on this soil. Average yields of general farm crops on most of this phase are quite satisfactory.

In many of the small areas bordering muck, where the type occurs in sandy, stony ridges, crop production is very low, and on the upper part of the areas near Forest City the soil is more suited for use as pasture. The soil is not strikingly deficient in plant food constituents, but when used for cultivated crops it will respond to applications of farm manure, which should be used in liberal amounts. It is acid in the surface layers and lime should be applied. Phosphorus fertilizers will undoubtedly prove of value, also, in some cases. In a few minor areas, drainage is needed, but in general the type is well drained and in places may be excessively drained. The addition of organic matter is particularly necessary where the surface soil is shallow and the sandy and gravelly subsoil approaches the surface. There may be considerable washing or gullyng of the type in the strongly rolling areas, and in some cases it would be most desirable to keep the soil in hay or pasture. In general, however, it may be cultivated and serious injury from washing may be prevented by building up the organic matter content thru the use of farm manure or leguminous green manure crops and taking other precautions to prevent the washing away of the surface soil.

CLARION LOAM (STEEP PHASE) (151)

This is a very minor type in the county, covering only 0.3 percent of the total area. It occurs in a few small areas north of Lake Mills and in scattered areas in other parts of the county, chiefly, however, in the eastern part, in association with the rolling phase Clarion.

The soil is a yellowish-brown clay loam, with a thin layer of darker soil on the crests of ridges and on the more gradual slopes. In most cases the surface is more or less stony and pockets of gravel are of common occurrence. Highly calcareous glacial material is often exposed at the surface. The narrow areas of this type, occurring along streams and lake beds, are steep, untillable slopes, and a few areas at other points are local elevations which are usually stony and unsuitable for cultivated crops. Only a few small areas are cultivated, and most of the phase is utilizable only as pasture land. Much of the larger areas north of Lake Mills are ridges covered in part with a growth of oak.

WEBSTER CLAY LOAM (56)

The Webster clay loam is the second largest soil type in the county, covering 10.7 percent of the total area. It occurs in all parts of the county, the largest areas being found in Grant township in the southwestern part of the county. Irregular areas, some rather considerable in size, occur in other parts of the county, chiefly in the central and western portions. The areas in the eastern part are relatively small and unimportant. The smaller areas in the northern and central parts of the county are quite variable, including small spots of Clarion loam which cannot be mapped out, and also small muck beds which cannot be shown separately. Occasionally swamp symbols in the areas of Webster clay loam will denote a mucky condition.

The surface soil of the Webster clay loam is a black mellow silty clay, containing a little coarse sand and a few pebbles, and extending only a few inches in depth. The soil then becomes a slightly compact silty clay loam or in some cases a sticky silty clay. Below 18 inches the color changes to a dull grayish-

black, or very dark drab and at lower depths it becomes a light drab, slightly mottled with yellow iron stains. The light-colored lower subsoil is generally a sticky silty clay, but occasionally it may contain considerable sand, gravel and small stones. The surface soil is somewhat variable, particularly in the north-western and central parts of the county, in some places having a shallow covering of muck and in others being somewhat lighter in texture and resembling the Clarion loam. The lower subsoil is high in lime, and in many cases the large lime content extends up thru the surface soils. The type is level to depressed in topography and drainage is necessary for satisfactory crop production. Tiling is very effective in reclaiming areas of this type and it is usually the first treatment needed to insure satisfactory crop growth.

General farm crops are grown on the Webster clay loam, practically all of the type being under cultivation. Some areas have not been cultivated, owing to inadequate drainage, but the installation of tile will permit of the growing of general farm crops. Corn is grown most extensively and in favorable seasons yields of 60 to 70 bushels per acre are secured. Insufficient drainage and the occurrence of "alkali" spots reduce crop yields to some extent. Average yields of oats range from 60 to 70 bushels per acre in favorable seasons, the short-strawed early varieties being most desirable for use on this soil. If the season is wet, the crop may suffer from lodging. Wheat and barley give good returns in average years and clover and timothy mixed is the most common hay crop, usually giving heavy yields. Red clover alone might be grown very satisfactorily, and alfalfa would prove a valuable crop when drainage is established.

This soil is a highly productive one and, when adequate drainage is insured, crop yields are very satisfactory. Small applications of manure might be of value on newly drained areas, and where "alkali" spots occur, large additions of fresh horse manure are recommended to aid in removing the "alkali" condition. The soil is usually high in lime content, but as it is better drained and brought



Fig. 7. Webster clay loam, Winnebago county.

under cultivation, the surface soil will become deficient in lime. Phosphorus fertilizers might be of value in some instances now, but these materials should not be employed until they are tested. They will be needed, however, in the future.

TERRACE TYPES.

There are two terrace soils in the county, classified in the Waukesha and Fargo series. They are of minor importance, together covering only 2.5 percent of the total area.

WAUKESHA LOAM (60)

The Waukesha loam is the larger of the terrace types, covering 1.7 percent of the total area of the county. It occurs chiefly along Lime creek, the larger areas being found west of Forest City and east and north of Scarville. There are a few small areas along Blue Earth creek in the western part of the county and one area southwest of Scarville.

The surface soil of the type is a dark brown coarse-textured loam or sandy loam. At a depth of 8 to 10 inches it changes to a brown loam and the lower subsoil is a coarse loamy sand, grading at about 40 inches into coarse sand and gravel. In some areas the soil may be a clay loam and the lower subsoil a sticky, sandy, gravelly clay. Along the base of the uplands the type is usually a loam, with a heavy brown or yellowish-brown clay loam subsoil. In some places there are small muck beds, and in depressed or flat areas the type passes into Fargo silt loam. These variations occur in some of the areas northwest of Forest City and in the areas east of Scarville. In nearly all the areas along Lime creek, there are low, mound-like elevations where the soil is a sandy loam, with a rather coarse sand or gravel at a depth of 20 to 30 inches. In the western part of the county the areas are quite variable, some of them being brown loams with gravel at a depth of 4 to 5 feet, others being dark-colored heavy loam and some light in color and with sand and gravel rather close to the surface.

The topography of the Waukesha loam is generally undulating to gently rolling, the lighter variations of the type occurring as low ridges, while the heavier, darker-colored areas are quite level. The soil is well drained and in some places the drainage is excessive and the type is drouthy. This is true in many of the areas along Lime creek.

The Waukesha loam is practically all under cultivation and general farm crops are produced. Corn, oats, and wheat give satisfactory yields. The lighter variations of the type prove less desirable for general farm crops. Garden crops are grown to some extent and do well on this soil. Potatoes make large yields, and sorghum does well.

Crop yields may be increased to a considerable extent on this soil by proper soil treatment. It is chiefly in need of organic matter, and liberal applications of farm manure would be of much value, particularly on the lighter-colored and lighter-textured areas. Leguminous green manure crops would be of value in addition to manure, or in place of manure. The soil is acid and in need of lime. The phosphorus supply is insufficient for any considerable number of

crops and phosphorus fertilizers will need to be added in some form in the near future, and may be of value in some cases at the present time.

FARGO SILT LOAM (152)

The Fargo silt loam is a minor type in the county, covering only 0.8 percent of the total area. It occurs in small areas along Lime creek, chiefly northwest of Forest City and northeast of Scarville, the areas being associated with the Waukesha loam on the terraces.

In the areas near Scarville, the soil is a heavy black silty loam, overlying a black silty clay, sometimes quite sticky. The lower subsoil in these areas varies from a light-colored sticky silty clay to a rather loose sandy loam. In the areas northwest of Forest City the soil is a black loam to silty clay loam, the loam texture prevailing adjacent to the Waukesha. In topography this type is level to depressed and drainage is inadequate. The sandy or gravelly material may occur at a depth of several feet, but the texture of the soil prevents adequate removal of surface moisture. In wet seasons water may stand on the surface of the soil for long periods and tiling is very necessary.

Most of the areas west of Forest City along Twister Branch are cultivated and large crops of corn, oats and barley are secured. Timothy and clover also do well. In the undrained areas, or the areas where drainage is not adequate, the land is used for pasture or for the production of hay.

This soil is particularly in need of drainage if it is to be made productive, and when this is accomplished large crop yields may be secured. A small application of organic matter might aid on newly drained areas. "Alkali" spots occur occasionally after drainage is accomplished, and in such cases large amounts of manure should be applied. The soil is well supplied with lime. It will eventually require additions of phosphorus fertilizers, but at present these will probably not be needed.

SWAMP AND BOTTOMLAND SOILS.

There are four areas of swamp and bottomland soils in the county, covering a total of 13.6 percent of the total area of the county. There is one soil type of the Lamoure series, and areas of muck, peat and meadow.

MUCK (21A)

There is a rather considerable area of muck in the county, covering 5.2 percent of the total area. It occurs in numerous small areas in all parts of the county. The largest area is found northeast of Thompson, and other rather extensive areas occur southwest of Scarville, east and southeast of Amund and in the vicinity of Lake Mills. Muck consists of a black, finely divided material produced by the slow decomposition of plant remains under water. There is some admixture with mineral matter, and a large number of shells, consisting of carbonate of lime, occur.

The surface material is very loose and porous and in most instances shallow in depth. The subsoil is generally a clay, a fact which is of considerable importance in the reclamation of muck areas. Deep plowing and the mixing of this clay subsoil with the very fine surface material provides improved physical

conditions for crop growth and also supplies plant food, particularly potassium, in which muck is deficient.

Muck represents a period of change from the original peat into soil. It takes less time, therefore, to make muck productive or, in other words, to make it into soil, than it does in the case of peat, but the same treatments are needed in both instances. Drainage is of major importance, and when this is entirely adequate, muck will be changed into a good, productive soil in a comparatively short time. The same recommendations which were made regarding peat soils very largely hold true for muck areas. If drainage is made adequate, the soils will be benefited by fall plowing, and deep plowing and the frequent cultivation of such areas is valuable. Corn and small grains will not do well on these areas when newly drained, and a mixture of timothy and alsike clover is recommended. Vegetables produce satisfactory crops and onions, celery, tomatoes and potatoes have all been grown with excellent results. Cabbages, beets, turnips and other crops might also prove of value. After a few years of such a system of cropping, corn and small grains may be grown successfully.

LAMOURE SILT LOAM (153)

The Lamoure silt loam is one of the most important bottomland soils in the county, covering 5.2 percent of the total area. It occurs along the natural and artificial drainageways in the county, considerable areas being found along Lime creek, Pike's Run, Buffalo creek, North Fork Buffalo creek, Blue Earth creek, Beaver creek, Bear creek, and the various ditches which have been installed in the county. Many additional areas, some very small in size, occur in all parts of the county in the depressed, poorly-drained spots.

The surface soil of the Lamoure silt loam consists of 6 to 8 inches of a black, crumbly or rather spongy silt loam, which changes at lower depths to a sticky, silty clay, a little more compact than the surface soil. The lower part of the three-foot section is usually a sticky silty clay, with very little gravel or sand. In places it is a clay loam, or it may consist of a mixture of gravel and stones in a sticky, clayey mass. In many of the areas, spots of muck are included



Fig. 8. Peat and muck in bed of Rice lake.

which are too small to be separated, and where the type adjoins muck or peat areas, there is no well defined boundary line. The surface soil as a rule is high in lime content and in practically all cases the soil is rich in this material thru the three-foot section. There is some variation in the character and depth of the surface soil, in different localities, but these variations are minor in significance. In some cases the subsurface is a stiff, waxy clay and the subsoil is extremely variable, as has been indicated.

This soil is flat in topography and all of it along the natural drainageways is subject to overflow, and drainage is poor. In the areas along the artificial drainage channels and in the depressions in uplands, drainage may be more readily accomplished and cultivated crops may be grown. Much of the type is now used for hay or pasture and the areas along the various creeks of the county are utilized only for hay or pasture. When well drained, the type may be very productive and will produce as large yields of crops as the Webster clay loam; in fact, it is adapted to the same crops.

PEAT (21)

The occurrence of peat in Winnebago county has been mentioned earlier in this report and suggestions regarding the best treatments have been made. This material need not be discussed further at this point.

MEADOW (20)

There is a small area of meadow in the county, amounting to 0.5 percent of the total area. It occurs along Lime creek and includes an area which is but 2 to 3 feet higher than the average level of the water in the creek. The subsoil is almost constantly saturated and slight depressions are marshy. In the better locations the soil is often practically the same as Lamoure silt loam. In some of the marshy areas it is a mixture of muck and silt. There are areas where the surface consists of a series of hummocks, 2 to 3 feet across.

There is no tree growth on this soil, except an occasional willow. In the lower areas the vegetation consists chiefly of coarse water-loving grasses and sedges. Bluegrass grows to some extent on the hummocky areas and in general on the soil where it is not too wet. The black, mucky surface deposits rest upon beds of gravel. The material going to make up meadow is so extremely variable that it cannot be mapped as a soil type and must be considered as a mixture of various materials changing in composition with every flood. The land may be used for pasturage and hay, and some of it might be rendered tillable if it were protected from overflow and well drained.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

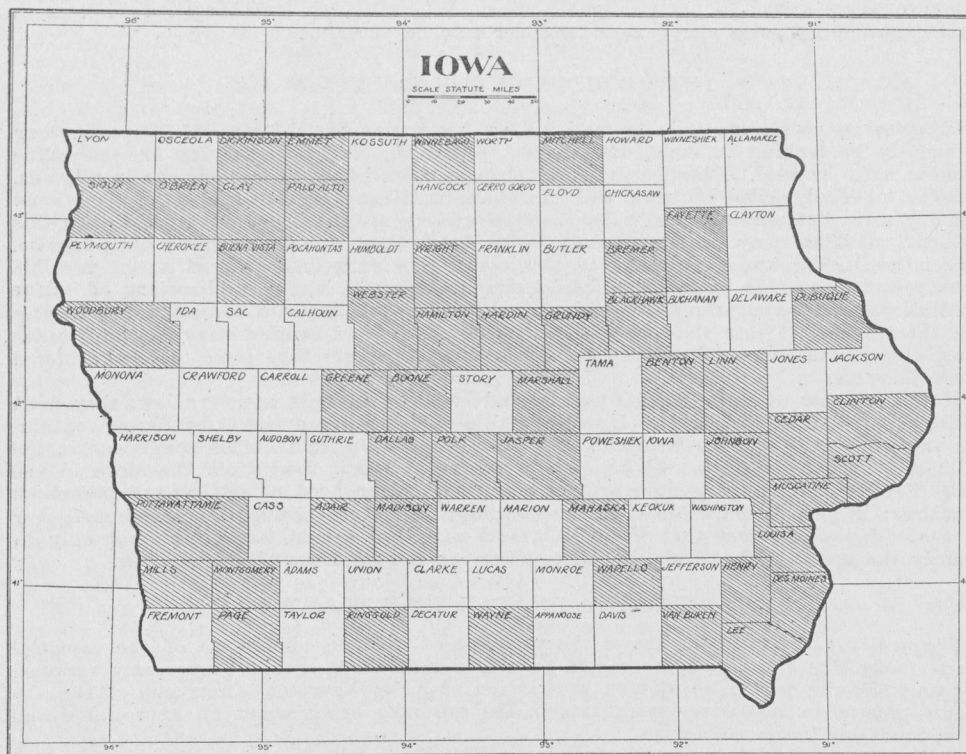


Fig. 9. Map of Iowa showing the counties surveyed.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavail-*

able. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, although there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate (NaNO₃)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	\$12.00	\$1.52	\$0.84	\$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about \$30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

*Bulletin 150, Iowa Agricultural Experiment Station.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between

two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important

in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are

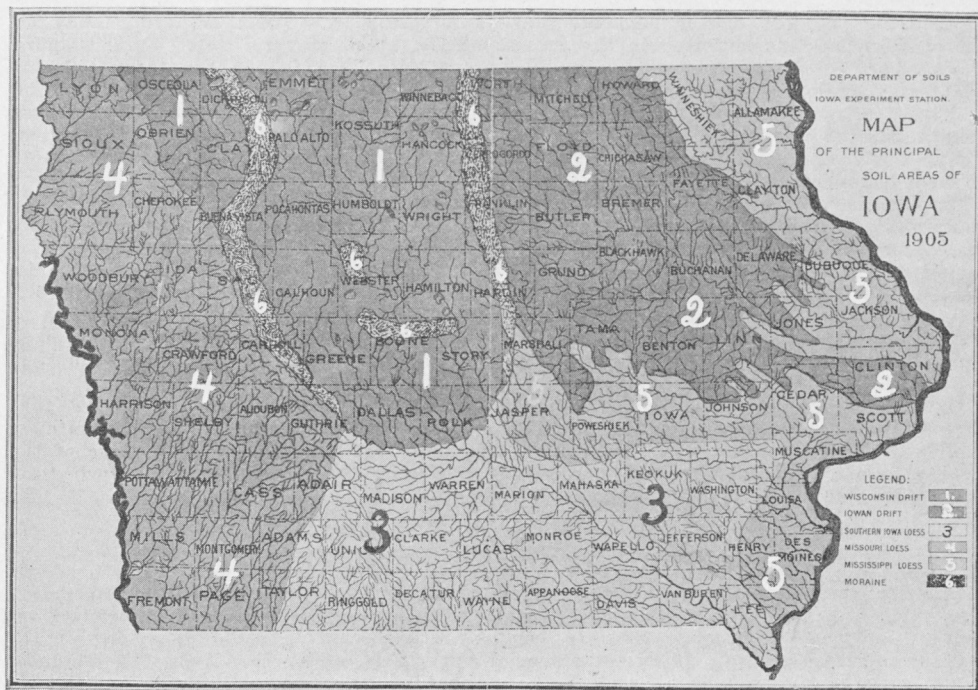


Fig. 10. Map showing the principal soil areas in Iowa

somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture of porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	{ All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	{ Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.